(1957) made similar observations for *Phyllosticta anisocarpa* also. Kanada (1957) working with seven members of the Mucorales reported that all the fungi studied by him were able to utilize the mixture of amino acids better than the individual ones.

Earlier investigations by the author (Ram Dayal [illegible]) had shown that various amino acids were not of equal value for the growth of these organisms. It was, therefore, considered desirable to study their influence when they were used in a mixture.

MATERIAL AND METHODS

The organisms under study, *viz.*, *Achlya apiana* Maurizio, *Isoachlya unispora* Coker and Couch, *I. toruloides* Kauffman and Coker and *Saprolegnia parasitica* Coker were isolated locally from a pond using hemp seeds as baits. Single spore cultures were made according to the method of Couch (1939). Five amino acids, *viz.*, histidine, arginine, aspartic acid, alanine, and valine were added to the basal medium* so as to furnish collectively 700 mgm. of nitrogen per litre. The pH of the medium was adjusted to 7.0 before autoclaving. The technique used for chromatographic analysis is briefly described as follows :

A circular piece of Whatman filter paper No. 1 having a diameter of 45 cm. with radial cuts according to the number of days was used. From the filtrate, drops of 0.5 ml. were placed at the portion located for the purpose. Equal volumes of drops of the known solution were also placed on the same chromatogram, to facilitate the identification of bands. The chromatograms were run with n-butanol-acetic acid and water (4 : 1 : 5) as solvent. The spray reagent consisted of 0.1% ninhydrin in normal butanol. The bands were finally developed by placing the chromatograms in the electric oven at a constant temperature of 100°C for about 1 to 2 minutes. The average Rf. values of the various amino acids have been calculated on the basis of the bands developed.

EXPERIMENTAL.

The Rf. values of different amino acids calculated are as follows : histidine (0.21), arginine (0.46), aspartic acid (0.53), alanine (0.5[illegible]) and valine (0.[illegible]). The daily dry weight of these fungi has been represented in the graph I.

It was observed that all the four fungi, *viz.*, *Achlya apiana*, *Isoachlya unispora*, *I. toruloides* and *Saprolegnia parasitica* utilized the mixture of amino-acids well. The growth of all these organisms continued to increase till the end of the experiment as evident from the graph.

It was also observed that *Saprolegnia parasitica* utilized arginine completely in 6 days, *Isoachlya unispora* in 13 days and *I toruloides* in 14 days. *Achlya apiana* could not finish this amino acid even at the end of 15 days. None of these fungi could totally consume the mixture of the amino acids within the experimental period.

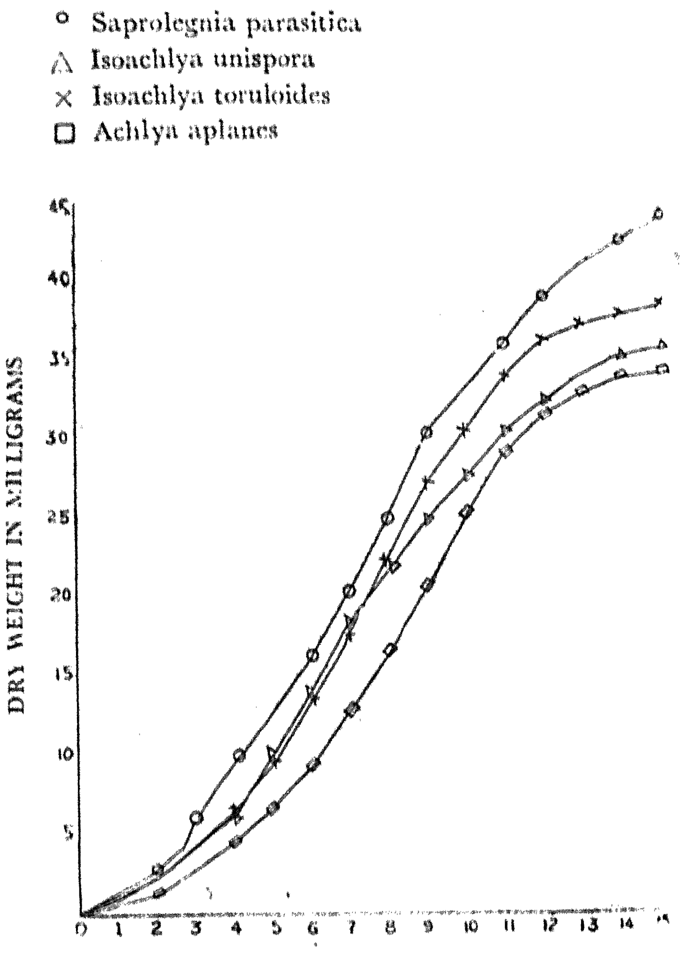
DISCUSSION

The present results clearly showed that closely related aquatic organisms exhibited different response for similar nutrients when supplied in a mixture. Chro

---

*KH_2PO_4 0.5 gm, $MgCl_2.6H_2O$ 0.5 gm, Na_2S 0.17 gm, glucose 5.0 gm, and double distilled water 1 litre.

matographic studies revealed that *Achlya aplanes* utilized all the amino acids from the mixture almost simultaneously. Bilgrami (1956) also obtained similar results for some species of *Phyllosticta*. *Saprolegnia parasitica* behaved in an entirely different manner as this organism consumed arginine within 6 days while other fractions of the mixture lasted till the last day of incubation period. *Isoachlya unispora* and *I. toruloides* also showed greater choice for arganine than for other amino acids but it was not so readily used up. Some members of the Mucorales, *viz*, *Mucor hiemalis* and *M. rouxii* (Raizada, 1957) have also been reported to exhibit greater liking for arginine than for other amino acids. Dry weight results were particularly interesting (Ram Dayal, 1958) as it was noticed that even though arginine was a preferential amino acid for *Saprolegnia parasitica*, *Isoachlya unispora* and *I. toruloides* but the mycelial yield was much less on this substance (arginine) than on a mixture of amino acids. It was also found that *Isoachlya unispora*, *I. toruloides* and *Saprolegnia parasitica* produced better mycelial growth on histidine than even on the mixture of all the five amino acids together. This shows that dry weight of an organism cannot be correlated with the rate of assimilatión of a particular amino acid, because a fungs may yield satisfactory growth on an amino acid even if that particular amino acid



Showing the growth of four fungi on the mixture of amino acids.

may not be entirely consumed from the medium. *Achlya aplanes*, however, made better growth on the mixture than on any individual source. The different behaviour of this fungus as compared to the rest of the organisms about its better growth on the mixture of amino acids can be interpreted on the basis of the general statement of Lilly and Barnett (1951, p. 106) in which they have mentioned that "The effect of one amino acid on the utilization of another varies with the amino acids involved and the specific fungs used."

SUMMARY

1. Selective assimilation of 5 amino acids from a mixture by *Achlya aplanes*, *Isochlya unispora*, *I. toruloides* and *Saprolegnia parasitica* was studied.

2. Arginine, which was a mediocre source for *Isochlya unispora* and *I. toruloides*, was preferentially utilized when given in a mixture.

3. Excepting *Achlya aplanes*, the rest of the fungi were not able to utilize the mixture of amino acids better than the individual ones.

4. None of the organisms were able to consume the mixture of amino acids within 15 days.

ACKNOWLEDGMENTS

The author takes this opportunity of expressing his sincere gratitude to Prof. R. K. Saksena, Head of the Botany Department, University of Allahabad under whose guidance this work was carried out. His thanks are also due to Dr. K. S. Bilgrami and Dr. B. B. S. Raizada for their valuable suggestions.

LITERATURE CITED

1. Bilgrami, K. S., 1956. Pathological and physiological studies of some fungi causing leaf spot diseases. D. Phil. Thesis, University of Allahabad.
2. Couch, J. N. 1939. Technic for collection, isolation and culture of Chytrids. *Jour. Elisha Mitchell, Sci. Soc.*, 55, No. 1, 208-214.
3. Foster, J. W., 1949. *Chemical activities of Fungi.* Academic Press, Inc., New York.
4. Leoniar, L. H. and V. G. Lilly, 1938. Studies on the nutrition of fungi I. Thiamin and the source of nitrogen *Phytopath*, 28, 531-548.
5. Leonian, L. H. and V. G. Lilly, 1940. Studies on the nutrition of Fungi IV. Factors influencing the growth of some thiamin requiring fungi. *Amer. Jour. Bot.*, 27, 18-26
6. Lilly, V. G. and H. L. Barnert, 1951. *Physiology of the Fungi* McGraw Hill publications.
7. Lilly, V. G. and L. H. Leonian, 1942. Nitrogen metabolism in *Saccharomyces cerevisiae*. *Proc. West. va Acad. Sci.*, 16, 60-70.
8. Raizada, B. B. S., 1957. Physiological cytological and Taxonomic studies of some Mucorales, D. Phil. Thesis, University of Allahabad.
9. Ram Dayal, 1958. Studies on some aquatic fungi, D. Phil. Thesis, University of Allahabad.
10. Steinberg, R. A., 1942. The Process of amino acid formation from sugars by *Aspergillus Niger*, *Jour. Agr. Research*, 64, 615-633.
11. Tandon, R. N. and K. S. Bilgrami, 1957. Nitrogen nutrition of *Phyllosticta artocarpina*, *Proc. Nat. Acad. Sci.*, 27 B, 269-273.

* original not consulted.

ON THE STRUCTURE AND MECHANISM OF THE SPIRÀCLES OF AULACOPHORA

By

R. S. SAINI

Department of Zoology, University of Saugar

[Received on 14th March 1959]

INTRODUCTION

As regards the respiratory system and the mechanism of respiration in adult Coleoptera a lot of work has been done on *Dytiscus* by a number of authors like Alt (1909), Brocher (1910, 1914 and 1916), Blunck (1917), and Heberdey (1938), but as far as the author is aware not much of work has been done on other beetles. In Chrysomelidae the respiratory system of *Galerucella birmanica* Jacoby has been described by Khatib (1946), and Saini (1954) has described the tracheal system of *Aulacophora*. The present account deals with the structure and mechanism of the spiracles in the three species of *Aulacophora—A. foveicollis* Luc., *A. atripennis* Fab., and *A. cincta* Fab.

MATERIAL AND TECHNIQUE

The structure of the spiracles was observed by making fresh mounts. Specially the muscles of the spiracles were studied by staining them with Mayer's paracarmine. The structures were also studied by the help of microtome sections.

OBSERVATION

In *Aulacophora*, there are nine pairs of spiracles. They are situated on the lateral sides of the body, two pairs being in the thorax and seven pairs in the abdomen. The first pair (or mesothoracic spiracles) are situated on the intersegmental membrane between the pro and mesothorax; the second pair or metathoracic spiracles are situated on the intersegmental membrane between the mesothorax and the metathorax and are normally covered over by the meso-epimeron. The first pair of abdominal spiracles are situated dorso-laterally on the intersegmental membrane between the meta-tergum and the first abdominal tergum. The second to sixth pair of abdominal spiracles are situated on the pleural membrane of the corresponding abdominal segments. The seventh pair of spiracles, however, are situated dorso-laterally on the pleuron of the seventh abdominal segment and are partly covered over by the pygidium. Out of the nine pairs of spiracles, the metathoracic spiracles are the largest in size, followed by the mesothoracic and first abdominal spiracles; the rest of the abdominal spiracles are more or less of the same size, but are much smaller than the first abdominal spiracles.

Each spiracular opening is contained in a small sclerotic plate called the peritreme, the peripheral edge of which is specially thickened. The external opening of each spiracle is called the atrial orifice and leads into a pit-like chamber or atrium which opens internally in the tracheal system by a tracheal orifice. The rim of the atrial orifice is slightly raised over the general surface of the peritreme. Internally, the atrium is provided with numerous fine cuticular hairs which act as a filter apparatus. The margin of the atrial orifice is never modified to form movable lips and takes no active part in the closing of the spiracle. The spiracles are closed by the action of a closing or occlusor apparatus which is situated at the tracheal orifice.

The Mesothoracic Spiracles (Fig. 1):

In the mesothoracic spiracles of *Aulacophora*, the atrial orifice is somewhat oval in shape. The external portion of the tracheal orifice is formed by a crescentic, elastic bar which is often called the closing bow which terminates in thickened processes at either end. The inner wall of the atrium opposite the closing bow forms a soft, convex fold called the closing band and it projects in the atrial lumen in such a way that the tracheal orifice appears crescentic in shape. The closing or occlusor apparatus consists of the closing bow and the closing band; the latter acts as a valve and becomes inflected over the mouth of the trachea by means of an occlusor spiracular muscle (m. 128) which runs between the two thickened terminal portions of the closing bow. The contraction of this occlusor muscle causes the two ends of the bow to come closer to one another and thus the closing band or valve is forced inwards until the tracheal aperture is completely closed. The opening of the tracheal orifice is effected by the contraction of a dilator spiracular muscle (m. 129) which arises from the ventral end of the closing bow and is inserted on the inner wall of the peritreme near its outer edge; the contraction of this muscle straightens the closing bow and thus the closing band is pulled back from the mouth of the trachea.

The Metathoracic Spiracles (Fig. 2):

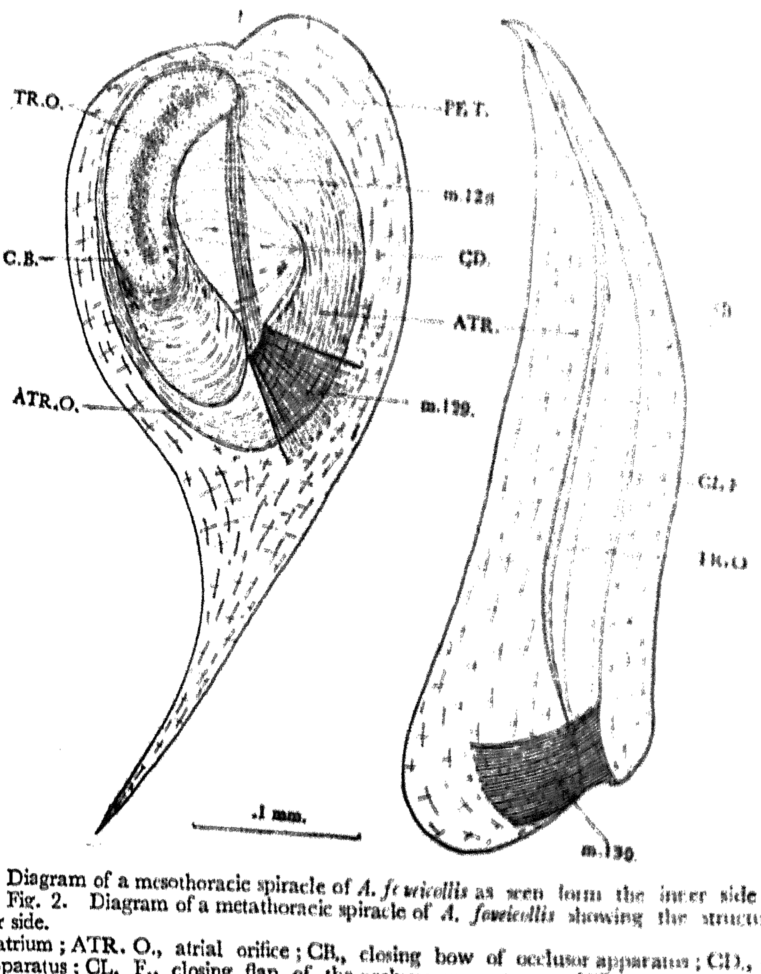


Fig. 1. Diagram of a mesothoracic spiracle of *A. foveicollis* as seen form the inner side showing its musculature. Fig. 2. Diagram of a metathoracic spiracle of *A. foveicollis* showing the structures as seen from the outer side.

ATR. atrium; ATR. O., atrial orifice; CB., closing bow of occlusor apparatus; CD., closing band of occlusor apparatus; CL. F., closing flap of the occlusor apparatus; m 128., occlusor spiracular muscle; m 129., dilator spiracular muscle; m 130., occlusor spiracular muscle of metathoracic spiracle; PET., eritreme; SB., sclerotic bar of metathoracic spiracle; TR. O., tracheal orifice.

In the metathoracic spiracles the atrial orifice is in the form of an elongated slit like opening. The occlusor mechanism is of the simple pinch-cock type consisting of two sclerotic bars in the opposite walls of the atrium near the tracheal orifice with an occlusor spiracular muscle (m. 130) stretched between their lower ends. The contraction of this muscle brings the lower ends of the two bars together and thus closes the tracheal opening; this closure is further helped by the fact that the margin of the inner bar is produced inwards into a soft, narrow band-like process which projects in the lumen of the atrium and acts as a closing valve. The dilator spiracular muscle is absent in the metathoracic spiracles, and its opening is effected by the relaxation of the occlusor spiracular muscle.

The Abdominal Spiracles (Fig. 3):

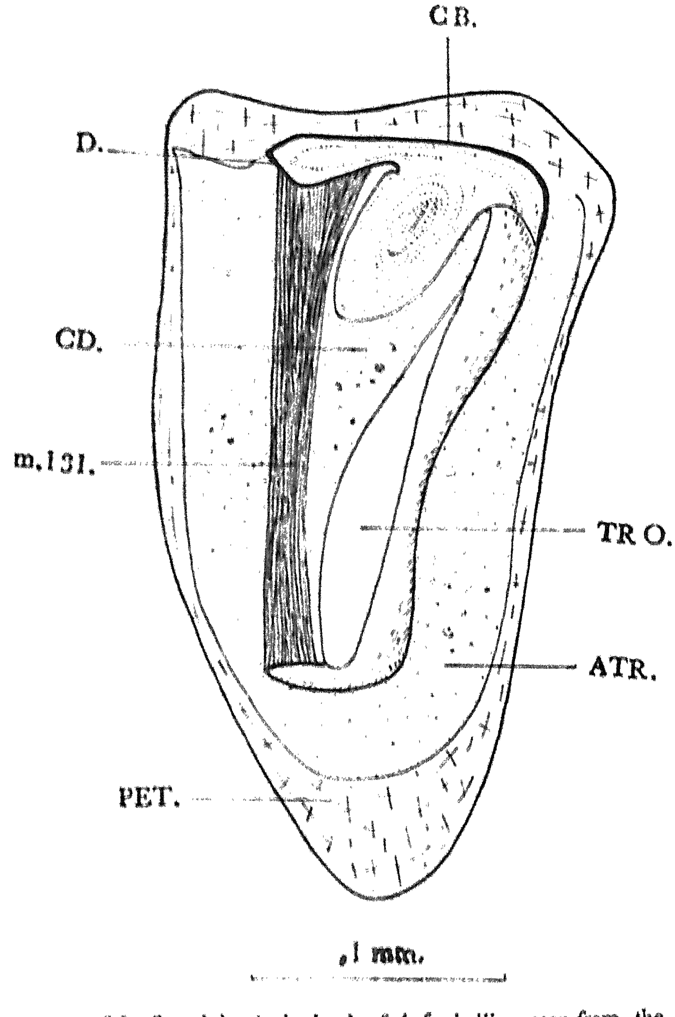


Fig. 3. Diagram of the first abdominal spiracle of *A. foveicollis* as seen from the inner side showing its musculature.

ATR., atrial orifice; CB., closing bow of occlusor apparatus; CD., closing band; D., dorsal process of closing bow; m. 131., occlusor spiracular muscle; PET., peritreme; TRO. tracheal orifice.

In the first abdominal spiracle, the atrial orifice is oval in shape. The closing bow differs from that of the mesothoracic spiracle in the fact that the upper end of the bow is produced into a dorsal process and the occlusor spiracular muscle (m. 131) extends from it to the ventral process of the bow. The closing of the tracheal orifice is effected by the contraction of this muscle which brings the two ends of the bow closer to each other as in the mesothoracic spiracles and thus the closing band or valve which projects from the opposite wall of the atrium closes the opening of the trachea. A dilator spiracular muscle is absent. The structure and occlusor mechanism of the other abdominal spiracles is similar to that of the first abdominal spiracle though these posterior abdominal spiracles are much smaller in size.

DISCUSSION

The spiracles and their closing mechanism in insects have been studied by a number of authors, among whom the works of Krancher (1881), Landois and Thelen (1867), Alt (1909), Bergold (1935), and Hassan (1944) may be specially mentioned. Among the Coleoptera, Alt (1909) and Korschelt (1924) have described the spiracles in *Dytiscus* and Khatib (1946) has described the spiracles in *Galerucella birmanica* and here in this discussion a comparison has been made between the structures of the spiracles of *Aulacophora* and *Galerucella* as they belong to the same sub-family.

The number of thoracic and abdominal spiracles are the same in *Aulacophora* and *G. birmanica*, i. e., two thoracic and seven abdominal ones. In both these insects, the metathoracic spiracles are the largest ; in *Aulacophora* the mesothoracic spiracle is larger than the first abdominal spiracle, but in *G. birmanica*, according to Khatab, the first abdominal spiracle is larger than the mesothoracic spiracle. In *G. birmanica*, the two thoracic spiracles are similar, both in their structure as well as in their mechanism of closure. In this insect, each thoracic spiracle "is provided with an external closing apparatus in the form of a pair of movable right and left lips united ventrally in a sclerotic lobe. Both the lips are fringed with very fine hairs. By the approximation of the lips, the aperture between them is closed" (Khatib, 1946, p. 27). Thus, both the thoracic spiracles of *G. birmanica* have the 'external liptype closing apparatus', as is the case with the metathoracic spiracles of *Dytiscus*, described by Alt (1909) and Korschelt (1924). In *Aulacophora*, however, in both the meso-and metathoracic spiracles, the external lips are immov-able and fixed, and the closing apparatus, lies at the inner end of the atrium, *i.e.*, they are of the "inner closing type". In the mesothoracic spiracles, the occlusor mechanism belongs to the 'single valve subtype', while in the metathoracic spiracles, the occlusor mechanism belongs to the 'pinch-cock or double valve subtype' as described by Snodgrass (1935, page 442-443). These spiracles and their occlusor muscles have been already described in detail before and need no repetition here.

In *G. birmanica*, all the abdominal spiracles are essentially similar, except for their size and are provided with a occlusor mechanism of the 'inner closing type', which "consists of a pair of chitinised plates guarding the trachral orifice which is situated at the base of an open atrium" (Khatib, 1946, p. 28). In *Aulacophora* also all the abdominal spiracles have an occlusor mechanism of the "inner closing type". From Khatib's account, it is difficult to find out if the abdominal spiracles have an inner closing mechanism of the 'pinch-cock subtype' or of the 'single valve subtype' and he has also not described their muscles. In *Aulacophora*, the occlusor mechanism of the abdominal spiracles belong to the 'single valve subtype' as described by Snodgrass. These spiracles and their occlusor muscles have been already described before. The mesothoracic and abdominal spiracles, though both belong to the 'single valve subtype', however, differ in details. In the

mesothoracic spiracles, the closing bow is crescentic and its two ends are thickened; the occlusor spiracular muscle runs between these two thickened portions and a dilator spiracular muscle extends from the ventral end of the closing muscle and is inserted on the wall of the peritreme. In the abdominal spiracles, however, the upper end of the closing bow is produced laterally into a well developed dorsal process and the occlusor spiracular muscle extends from its tip to the small ventral process of the bow; moreover, a dilator spiracular muscle is absent in the abdominal spiracles.

SUMMARY

In *Aulacophora*, there are nine pairs of spiracles. The matahoracic spiracle is the largest. In all the spiracles the mechanism of occlusion is of "inner closing type". In the mesothoracic and the abdominal spiracles it is of the "single valve type" but in the metathoracic spiracles it is of the "pinch cock or double valve type".

ACKNOWLEDGMENT

The author is very much thankful to Prof. D. S. Srivastava for valuable guidance and suggestions.

REFERENCES

Alt, W. 1909. "Uber den Bau der Stigmen von *Dytiscus marginalis*". *Zool. Anz.*, 34 : 793-799.

Bergold, G. 1935. "(Form of spiracles in beetles from different environments".) *Z. Morph. Oekol. Tiere*, 29 : 511-598.

*Blunck, H. 1917 "(Respiration, &c. Dytiscus, Col.)." *Z. Wiss. Zool*, 117 : 1-120.

Brocher, F. 1910. "(Respiration in adult aquatic insects-*Dytiscus*, Col.)". *Ann. Biol. Lac.*, 4 : 383-398.

*——1914. "(Respiration in *Dytiscus*)." *Ann. Biol. Lac.*, 7 : 1-39.

——1916. "Nouvelles observations biologiques et physiologiques sur les Dyticides." *Arch. Zool. Exp. Gen.*, 55 : 483-514.

Hassan, A. A. G. 1944. "The Structure and mechanism of the spiracular apparatus in adult Diptera and certain other group of insects." *Trans. Roy. Ent. Soc.* Lond., 94 : 103-154.

Hebenley, R. F. 1938 "(Respiration of Dytiscidae)". *Z. Morph. Oekol. Tiere*, 33 : 667-734.

Imms, A. D. 1958. "A General Text-Book of Entomology." London.

Khatib, S. M. H. 1946. "The external morphology of *Galerucella birmanica* Jac." *Proc. Ind. Acad. Sci.*, B, 23 : 1-38.

——1946a. "The internal anatomy of *Galerucella birmanica* Jac., Coleoptera, Polyphaga, Chrysomelidae, Galerucinae." *Proc. Ind. Acad. Sc.*, 24 : 35-54.

Korschelt, E. 1924. "Bearbeitung Einheimischer Tiere. *Dytiscus marginalis*." Leipzig.

*Krancher. 1881. "Der Bau der Stigmen bei den Insekten." *Zeits. wiss. Zool.*, 35 : 505-574.

*Landois, H. and Thelen, W. 1867. "Der Tracheenverschluss bei den Insekten." *Zeitschr. wiss. Zool.* 17 : 185-124.

Saini, R. S. 1954-55. "Studies on the anatomy of the genus *Aulacophora*". *Saugar Univ. Jour.*, 1 (4) : 111-125.

Sondgrass, R. E. 1935. "Principles of Insect Morphology". New York.

Steinke, G. 1919. "Die Stigmen der Kaferlarven". *Arch. Naturg.*, 85, Abt. A., Heft 7 : 1-56.

(*Papers not seen in original).

ON THE OCCURRENCE OF THE LARVAL FORM, HYDATID CYSTS OF *ECHINOCOCCUS GRANULOSUS* (BATSCH, 1786), FROM THE SHEEP OF DELHI STATE

By

L. N. JOHRI

Department of Zoology, University of Delhi

[Received on 7th January, 195[illegible]]

A survey for the helminth parasites from the animals killed in the local slaughter houses has revealed the presence of Hydatid cysts of *Echinococcus granulosus* (Batsch, 1786) from the sheep. Out of forty-five sheep examined, only four were found infected with Hydatid cysts. Two cysts were recovered from the lungs of two animals, one from the liver and another from the sub-cutaneous region of the abdomen of the animal.

The largest cyst, available from the lungs, measures 7·90 mm. × 5·90 mm. The outer wall of the bladder (*ectocyst*) acquires definitely laminated character and is essentially devoid of nuclei, while the inner layer of the bladder wall (*endocyst*) gives rise to the germinal layer of the Hydatid. A large number of brood

HYDATID CYST OF ECHINOCOCCUS GRANULOSUS (BATSCH,1786)

(semi - diagrammatic)

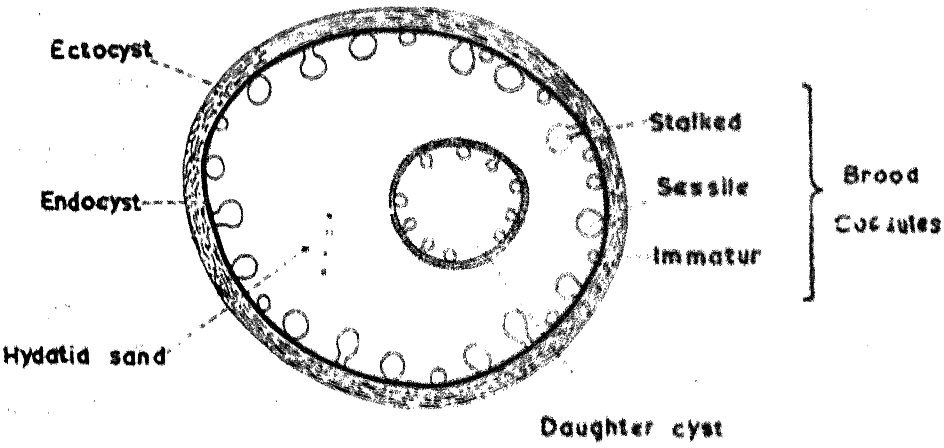


Plate I. Hydatid Cyst of Echinococcus granulosus (Batsch, 1786)

capsules, in the form of minute vesicles, originate from the endocyst. Brood capsules, with distinct stalk and also the sessile ones where no stalk-like growth is developed, are attached to the germinal layer. Some daughter cysts, with the

diameter 1·0 mm.—1·2 mm., are found floating in the fluid of the cystic cavity. The daughter cysts further produce buds from its internal layer. The detailed information regarding the size, brood capsules, daughter cysts and Hydatid sand of Hydatid cysts from the different locations is given in Table 1.

TABLE 1

Comparative table of Hydatid cysts of *Echinococcus granulosus* (Batsch, 1786) as reported from the various locations in the body of the sheep

Location	Size		Brood capsules			Daughter cysts		
	Maximum length in mm.	Maximum width in mm.	Percentage of stalked form.	Percentage of sessile form.	Percentage of immature form	Stalked buds	Sessile buds	Hydatid Sand
1. Lung	7·90	5·90	36%	34%	30%	50%	50%	++
2. Lung	6·83	4·64	29%	40%	31%	68%	32%	++
3. Liver	5·94	4·86	18%	31%	51%	Absent	Absent	+
4. Sub-cutaneous region	6·23	3·80	8%	12%	80%	Absent	Absent	—

++ Plentiful

\+ Only a few

— Absent

From the above data, it is interesting to observe that these cysts thrive very well as the first preferrence in the lung and to a lesser degree in liver tissue of the sheep. Brood capsules from these two tissues, with stalks and without stalks and possessing rostellum and suckers, also indicate higher percentage in comparison to the immature forms where rostellum and suckers are not developed at all. The percentage of brood capsules (stalked and sessile) from the sub-cutaneous region is fairly low with a higher percentage of immature capsules. The daughter cysts possessing stalked and sessile buds (where no rudiments of rostellum and suckers are developed) and Hydatid sand are mainly available from the Hydatid cysts in the lung, while no daughter cysts are contained in Hydatid cysts either from the liver or from the sub-cutaneous tissues of the host. Hydatid sand (only a few) is available in Hydatid cysts from the liver while it is entirely missing from that of the sub-cutaneous region.

The larval form, Hydatid cysts of *Echinococcus granulosus* (Batsch, 1786) was first reported from Punjab by Gaiger (1910), subsequently Gaiger (1915) from India and Aggarwala (1925) from U. P. (Muktesar) further reported its occurrence. The present information together with the detailed and comparative data forms the first record of this parasite from Delhi State.

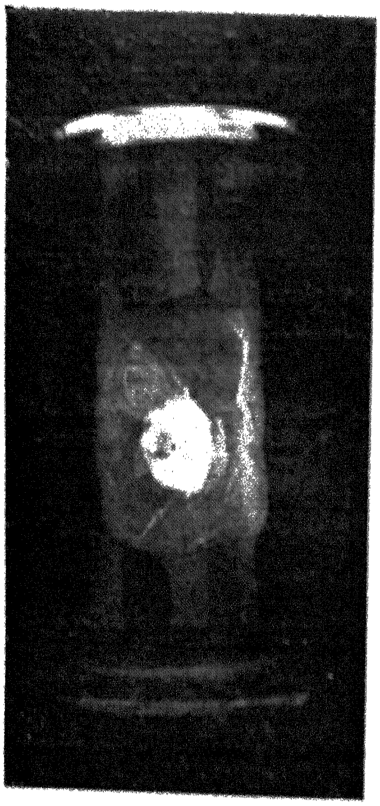


Fig. 1. Hydatid Cyst infection in the lung of sheep.

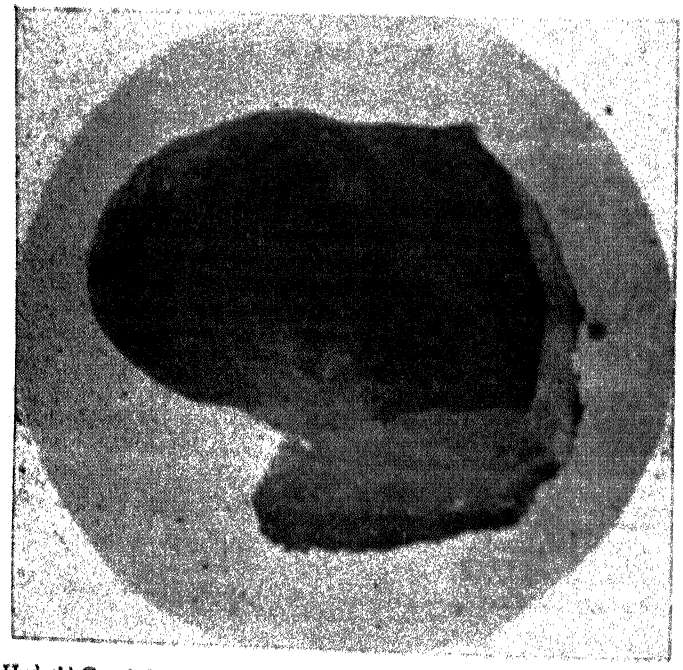


Fig. 2. Hydatid Cyst infection in the liver of sheep (dissected out to show the germinal layer).

SUMMARY

In course of a survey of helminth parasites from Delhi slaughter houses, the occurrence of the larval form, Hydatid cysts of *Echinococcus granulosus* (Batsch, 1786) is reported for the first time from the sheep of Delhi State. Hydatid cysts are available from the lung, liver and the sub-cutaneous tissues of the sheep. A comparative study of the brood capsules, daughter cysts and the Hydatid sand as available from the different tissues of the host, is undertaken. The percentage of the sessile, stalked and immature forms contained in the daughter cysts (together with stalked and sessile buds) is given in a comparative table. It is ascertained that the lung and liver tissues form the most thriving regions in comparison to the sub-cutaneous tissues in the body of the sheep.

ACKNOWLEDGEMENTS

The author is greatly indebted to Professor M. L. Bhatia for providing facilities to carry out the investigations in the Department of Zoology, University of Delhi and also to the Council of Scientific and Industrial Research for the financial assistance.

REFERENCES

Bhalerao, G. D., 1935. "Helminth parasites of the domesticated animals in India." *Scientific Monograph No. 6* of *I. C. A. R.*

Craig, C. F. & Faust, E. C., 1945. "Clinical Parasitology." Philadelphia.

Gaiger, S. H., 1910. "A preliminary check-list of the parasites of Indian domesticated animals". *Jour. Trop. Vet. Sc.*, 5, 65-71.

Gaiger, S. H., 1915. "A revised check-list of animal parasites of domesticated animals "in India." *Jour. Comp. Path. Therp.*, 28, 67-76.

Southwell, T., 1930. "The Fauna of British India, including Ceylon and Burma, Cestoda, 2".

SEASONAL INFESTATION OF *INDOPLANORBIS EXUSTUS* (Deshayes) WITH FURCOCERCOUS CERCARIAE

By

R. N. SINGH

College of Science, Raipur (M. P.)

[Received on 22nd May 1958]

INTRODUCTION

One of the first observations to be made on a seasonal distribution of cercariae is that of schistosome cercariae in Egypt by Manson-Bahr and Fairley in 1920. Soparkar (1921) observed the prevalence of cercariae of *S. spindalis* throughout a period of two years. The seasonal infestation of *Nassa obsoleta* (Say) with cercariae was investigated by Miller and Northup (1926). A two year survey of the seasonal infestation of *Planorbis trivolvis* (Say) was carried out by McCoy (1928). Chatterji (1933) published a note on the ecology of an echinostome cercaria, *Cercaria palustris* Chatterji, 1933 in Allahabad. Miller (1926, 28 and 29) presented his observations on the behaviour and reactions of several species of cercariae to light and mechanical stimuli. Similar studies were made by Miller and Mahaffy in 1930 and Miller and McCoy (1930). However, the most outstanding contribution towards the understanding of relation of cercariae to environment is that of Wesenberg-Lund (1934) who described many new species of cercariae and discussed the biology of each group. Miller (1936) made a study of North American cercariae and produced notes on relative abundance and distribution of several species. The effect of cercariae on hosts was studied by Rothschild (1936). Cort, MacMullen and Brackett (1937) carried out an ecological study for two years on cercaiae infecting a single species of snail, *Stagnicola emarginata angulata* (Sowerby). In this study, the authors have made a sufficiently careful analysis of cases of multiple infections.

The present work deals with infections in the common Indian snail, *Indoplanorbis exustus* (Deshayes) with furcocercous cercariae belonging to four groups: Strigeid, Clinostome, Spirorchid and Schistosome. The collection and examinations of snails from different localities in Allahabad district extended over a period of about two years as shown in Table I.

TABLE 1

Locality	Time of Collection	Number Collected	No. infected	Species of Cercariae
Hundia	17-8-'48 to 25-8-'48	378	10	*C. anuri* Singh, 1952
Sobatiabagh	3-9-'48 to 18-9-'48	360	3	*C. anuri* Singh, 1952
			2	*C. S. indicum* Srivastava and Dutt, 1951
			1	*C. Plasmiorchis orientalis* Singh, 1952
			1	*C. bioculata* Singh, 1952
Hundia	18-9-'48 to 22-9-'48	174	2	*C. anuri* Singh, 1952
			2	*C. bioculata* Singh, 1953
Sobatiabagh	30-9-'48 to 29-10-'48	492	1	*C. bioculata* Singh, 1953
			4	*C. S. indicum* Srivastava and Dutt, 1951
			6	*C. hornifurca* Singh, 1953
			1	*C. longicaudata* Singh, 1953
Piparahia	12-11-'48	66	1	*C. Plasmiorchis orientalis* Singh, 1952
Sobatiabagh	13-11-'48	120	nil	
Phulpur	18-11-'48	110	2	*C. Plasmiorchis orientalis* Singh, 1952
Alfred Park	2-12-'48 to 10-1-'49	595	56	*C. S. indicum* Srivastava and Dutt, 1951
			7	*C. hornifurca* Singh, 1953
			2	*C. longicaudata* Singh, 1953
			3	Double infection with *C. hornifurca* Singh, 1953 and *C. S. indicum* Srivastava and Dutt, 1951

Locality	Time of Collection	Number Collected	No. infected	Species of Cercariae
Ahimanpur	20-1-'49	1686	17	*C. S. indicum* Srivastava and Dutt, 1951
	to			
	18-6-'49		2	*C. bioculata* Singh, 1953
			3	*C. (Glanstome) hunterii* Singh, 1952
			9	*C. ahimanpurensis* Singh, 1953
Alfred Park	18-8-'49	264	15	*C. anuri* Singh, 1952
	to			
	23-8-'49			
Nurpur	24-8-'49	63	nil	
Ismailgunj	25-8-'49	322	3	*C. S. indicum* Srivastava and Dutt, 1951
	to			
	4-9-'49		1	*C. anuri* Singh, 1952
Ahimanpur	5-9-'49	179	1	*C. Plasmiorchis orientalis* Singh, 1952
			2	*C. bioculata* Singh, 1953
			8	*C. S. indicum* Srivastava and Dutt, 1951
			2	*C. anuri* Singh, 1952
Ismailgunj	8-9-'49	47	1	*C. S. indicum* Srivastava and Dutt, 1951
			3	*C. anuri* Singh, 1952
Ahimanpur	15-9-'49	305	1	*C. sphericauda* Singh, 1952
	to			
	22-9-'49		6	*C. S. indicum* Srivastava and Dutt, 1951
			1	*C. Plasmiorchis orientalis* Singh, 1952
Delhupur	10-10-'49	827	1	*C. anuri* Singh, 1952
	to			
	25-10-'49		4	*C. hornifurca* Singh, 1953
			3	*C. Plasmiorchis orientalis*, 1952
			2	*C. S. indicum* Srivastava and Dutt, 1951

TABLE 1—(*Concld.*)

Locality	Time of Collection	Number Collected	No. infected	Species of Cercariae
Alfred Park	27-10-'49	48	1	*C Plasmiorchis* Singh, 1952
			1	*C. anuri* Singh, 1952
			1	*C. hornifurca* Singh, 1953
			1	*C. bioculata* Singh, 1953
Delhupur	3-11-'49 to 23-11-'49	549	1	*C. bioculata* Singh, 1953
			2	*C. Plasmiorchis orientalis* Singh, 1952
			1	*C. hornifurca* Singh, 1953
			1	*C. S. indicum* Srivastava and Dutt, 1952
			4	*C. anuri* Singh, 1952
Ahimanpur	3-11-'49	147	2	*C. Plasmiorchis orientalis* Singh, 1952
			1	*C. longicaudata* Singh, 1953
			1	*C. ahimanpurensis* Singh, 1953
			2	*C. S. indicum* Srivastava and Dutt, 1951
Delhupur	7-12'49 to 11-2-'50	406	1	*C. delhupurensis* Singh, 1953
Ahimanpur	27-3-'50 to 11-6-50	919	6	*C. S. indicum* Srivastava and Dutt, 1951
			1	*C. delhupurensis* Singh, 1952
			2	*C. sphericauda* Singh, 1952
			4	*C. hornifurca* Singh, 1953
			4	*C.* (*Clinostome*) *hunteri* Singh, 1952
			1	*C. longicaudata* Singh, 1953
			2	*C. Plasmiorchis orientalis*, Singh, 1952

TABLE II

Regions of Specific Cercarial Infestation

LOCALITY	CERCARIAE
Ahimanpur	*C. Plasmiorchis orientalis* Singh, 1952
	C. Clinostome hunterii Singh, 1952
	C. S. indicum Srivastava and Dutta, 1951
	C. bioculata Singh, 1953
	C. longicaudata Singh, 1953
	C. hornifurca Singh, 1953
	C. sphericauda Singh, 1952
	C. delhupurensis Singh, 1953
	C. ahimanpurensis Singh, 1953
	C. anuri, Singh, 1952
Alfred Park (Allahabad Proper)	*C. Plasmiorchis orientalis* Singh, 1952
	C. hornifurca Singh, 1953
	C. longicaudata Singh, 1953
	C. anuri Singh, 1952
	C. bioculata Singh, 1953
	C. S. indicum Srivastava and Dutt, 1951
Delhupur	*C. Plasmiorchis orientalis* Singh, 1952
	C. hornifurca Singh, 1953
	C. delhupurensis Singh, 1953
	C. anuri Singh, 1952
	C. S. indicum Srivastava and Dutt, 1951
Hundia	*C. anuri* Singh, 1952
	C. bioculata Singh, 1953
Ismailgunj	*C. anuri* Singh, 1952
	C. S. indicum Srivastava and Dutt, 1951
Piparahia	*C. Plasmiorchis orientalis* Singh, 1952

TABLE II—(*Contd.*)

Regions of Specific Cercarial Infestation

LOCALITY	CERCARIAE
Phulpur	*C. Plasmiorchis orientalis* Singh, 1952
Sobatiabagh	*B. anuri* Singh, 1952
	C. bioculata Singh, 1953
	C. hornifurca Singh, 1953
	C. longicaudata Singh, 1953
	C. S. indicum Srivastava and Dutt, 1951
	C. Plasmiorchis orientalis Singh, 1952

TABLE III

Time of appearance and percentage of Infection

Species of cercariae	No. of snails collected	Period of Collection	Percentage	Time of Appearance
Crcaria S. indicum Srivastava and Dutt, 1951	8057	August 1948 to June, 1950	1·3	Throughout the year
Cercaria (Plasmiorchis) orientalis Singh, 1952	,,	,,	0·2	Sept. Oct. Nov. and June.
Cercaria (Clinostome) hunterii Singh, 1952	,,	,,	0·08	March, May and June.
Cercaria anuri Singh, 1952	,,	,,	0·4	August, Sept. and Oct.
Cercaria sphericauda Singh, 1952	,,	,,	0·03	Sept. and May.
Cercaria hornifurca Singh, 1953	,,	,,	0·8	Oct., Dec. Jan., May and June.
Cercaria longicaudata Singh, 1953	,,	,,	0·11	Oct., Nov. Dec. and May.
Cercaria bioculata Singh, 1953	,,	,,	0·12	Sept., Oct. Mach and June.
Cercaria delhupurensis Singh, 1953	,,	,,	0·004	Dec. and May.
Cercaria ahimanpurensis Singh, 1953	,,	,,	0·12	Nov., May and June.

During the present survey a fairly definite seasonal incidence of infection with cercariae has been noted and the results are in agreement with those of the previous workers. Manson-Bahr and Fairley (1920) recorded the highest percentage of infection in snails with chistosome cercariae in the month of December. Johnston (1920) observed that the appearance of cercariae of *Echinostomum revolutum* is dependent on the habits of the definitive hosts. Sewell (1922) observed that cercariae are shed primarily in December and July. Miller and Northup (1926) concluded that there is a semi annual rise and fall in the larval trematodes infestation of *Nassa obsoleta* (Say). Chatterji (1933) found that *Cercaria palustris* was prevalent in September with low infections in December and January. However, Wesenberg-Lund (1943) reported that there is no such regular seasonal fluctuations in the infection with larval trematodes.

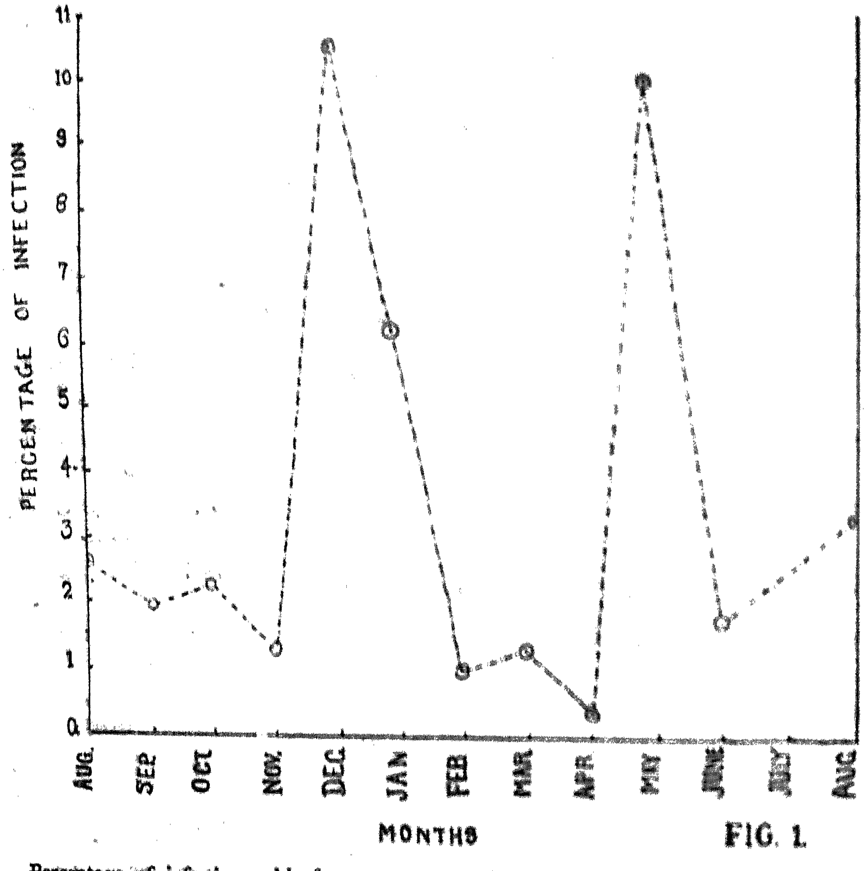


FIG. 1.

Fig. 1. Percentage of infection with furcocercous cercariae in *Indoplanorbis exustus* (Deshayes) during August, 1948 to August, 1949.

A study of the seasonal infection in snail *Indoplanorbis exustus* (Deshayes) from month to month in Allahabad during the period August, 1948 to July, 1949 shows two peaks indicating the highest percentage of infection with cercariae (Fig. 1). About 2·6% of snails are infected in August and this is some what regular with an infection of 2% in September to 2·23% in October following which there is a fall in November to 1·3%. Suddenly the rate of infection rises to a maximum of 10·5% in December. Beginning with 6·06% infection in January, there is again a gradual decrease in the degree of infection to about 1·0% in February, 1·3% in March till a minimum of 0·31% is reached in the month of April. This is following by another rise in May to 9·9. In June, there is again a fall in the degree of infection to 1·7%, and after this period the rains start so that during July there is overflow of water in ponds and the molluscs can only be found with great difficulty. Towards the end of summer and early rainfall, the percentage of infection decreases to about 3·28% in August. Observations on distribution of individual species of cercariae also explains the tendency of rise and fall in the rate of infection in snails.

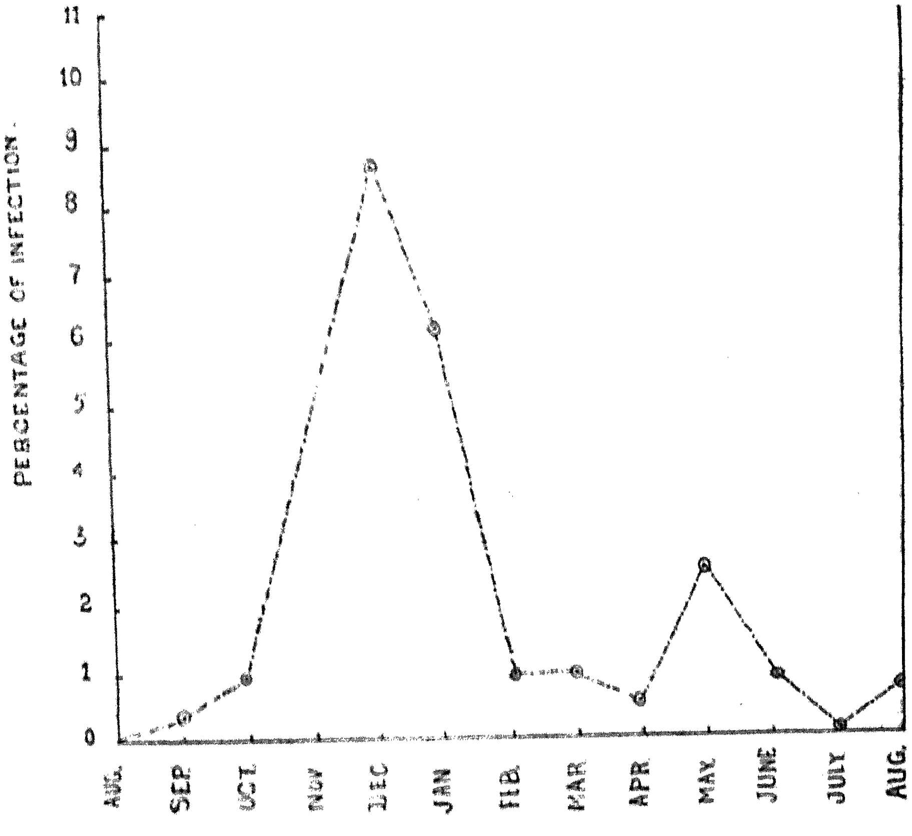


FIG. 2.

Fig. 2. Percentage of infection with cercaria of *Schistosoma indicum* in *Indoplanorbis exustus* (Deshayes) during August, 1948 to August, 1949.

Infection in snails with the cercariae of *S. indicum* is prevalent throughout the year but the infection rate varies from month to month (Fig. 2). There is 0·35% infection in September, 0·9% in October and apparently no infection in November. However, there is a rapid increase to 8·63% in December and 6·1% in January. After this period, there is again a decrease to 0·9% in February, 0·9 in March and 0·4 in April. Then again, a rise to 2·5% in May is followed by a decrease to 0·9% in June and 0·6% in August.

The cercaria of *Plasmiorchis orientalis* (spirorchid) described by the author in 1952 is less prevalent and appears in September, October, November and June. It is found in those localities where fresh water tortories live. The adults are parasitic in the ventricle of tortories and the eggs are passed along with the feces. The percentage of infection in snails with this species is low (Table 3).

The clinostome cercaria, *Cercaria (Clinostome) hunterii* Singh, 1952 is prevalent in most of the collections and its distribution largely depends on to the habits of various types of herons in which the adult clinostomes live. The species of the fish *Ophiocephalus punctatus* and *Ophiocephalus gachua* that live in muddy waters serve as the common hosts for the metacercariae.

Among strigeid cercariae, *Cercaria anuri* Singh, 1952 is most common in all localities and generally found in the months August, September and October. It penetrates tadpoles of frogs and develops into a metacercaria of *Diplostomulum* type. The percentage of infection in snails with this species is about 0·4% in a total collection of 8057 snails. The next common species is *C. hornifurca* Singh, 1953 that is common in two localities, Sobatiabagh in Allahabad proper and Village Delhupur. It occurs in combination with cercaria of *S. indicum*. The other strigeid cercariae *C. ahimanpurensis* Singh, 1953; *C. bioculata* Singh, 1953 and *C. longicaudata* Singh, 1953 are present in most of the collections usually with 0·12% infection in snails. *C. ahimanpurensis* is common in November, March ond June; *C. bioculata* in September, October, March and June; *C. longicaudata* in October, November, December and May (Table III). A study of Table II will show that *C. bioculata* is prevalent in Ahimanpur, Hundia, Alfred Park and Sobatiabagh. *Cercaria longicaudata* is common in Ahimanpur, Sobatiabagh and Alfered Park. *Cercaria ahimanpurensis* is mostly restricted to ponds near village Ahimanpur from where it was collected. The infection with *Cercaria sphericauda* Singh, 1952 and *Cercaria delhupurensis* Singh, 1953 in snails varies from 0·02% to 0·03%. The former appears to be restricted to Ahimanpur area whereas the latter is common in Delpupur and Ahimanpur and could not be found in any other locality.

MULTIPLE INFECTIONS

In these investigations, cases of multiple infections were rare. The observations are in general agreement with those of Sewell (1922) and Dubois (1929) who also found that multiple infections are rare. Wesenberg-Lund (1934) recorded that double infections in mollusks are of common occurrence. Considering the mechanism that render double infections rare, Sewell (1922) and Dubois (1929) believe that peneration of the first miracidium renders the host unfit physiologically for further pentration either by destroying the chemotactic stimulus or by damaging the host stisuues and so prevent parasitic development. Cort *et el* (1937) after determining tastically the number of multiple infections that would occur by chance and comparing this number found that double infections with *Cercaria stagnicolae* and any

other species occur in about the numbers that would be expected by chance. They further observed that there is no immunity or antagonism occurring between trigeid species but on the other hand some sort of immunity or antagonism occurs between *Plagiorchid* species of cercariae. Rankin (1939) observed some antagonism with *Xiphidiocercariae*. In any case the mechanism for such immunity or antagonism has not yet been ascertained.

During present studies on furcocercous cercariae of four major groups: Spirorchid, Clinostome, Schistosome and Strigeid, snails with two species of cercariae were rarely found. The only combination was that of strigeid cercaria, *C. hornifurca* Singh, 1953 with the cercaria of *S. indicum*.

SUMMARY AND CONCLUSION

Seasonal infestation of the common Indian snail, *Indoplanorbis exustus* (Deshayes) with furcocercous cercariae belonging to four groups Schistosome, Strigeid, Spirorchid and Clinostome has been studied. The data presented here is an attempt to determine the periods when emergence of cercariae is normal and, therefore, infections showing only completely developed cercariae are included in the tables.

The complete infection records for ten species of cercariae prevalent during the period 1948-1950 from month to month as correlated in the tables show larger number of snails infected throughout the period with the cercaria of *S. indicum* having two peaks one in December and the other in May. The infection in snails is prevalent throughout the year. The next common infection is with strigeid cercariae and there is comparatively low incidence of infection with Clinostome and spirorchid cercariae.

The data clearly indicates that nearly all types of furcocercous cercariae seem to adopt easily *Indoplanorbis exustus* as a host in India. The studies confirm the view of Miller and Northup (1926) that there is semi-annual rise and fall in the incidence of infection which may be due to the migratory habits of the definitive hosts and the degree of their infestation as well as the life span of the snail host. However, some times this may not be true as neither the degree of infection nor the nature of cercarial fauna of a locality is predictable from one year to the next. This is because of the stock of the snails may be reduced so as to constitute a poor reservoir for the next year.

Further a particular species of cercaria may be found only once or twice in a given locality even though collections are continued over several years. Table 1 shows one such form *C. sphericauda* Singh, 1952 which was found twice in a two years period. Many of the cercariae apper to be distributed over the entire area whereas a few remain isolated in particular areas.

ACKNOWLEDGEMENTS

The author is grateful to Dr. H. R. Mehra, M.Sc., Ph.D. (Cantab), F.N.I., F.N.A.Sc., Ex Professor of Zoology, University of Allahabad for his keen interest and guidance in this work. Thanks are also due to U. P. Govt. Scientific Research Committee for awarding a scholarship for this work under Prof. H. R. Mehra. during the years 1948-1950.

REFERENCES

Chatterji, R. C. 1933. On an echinostome cercaria, *Cercaria paludinae* with notes on its life history. Bull. Acad. Sci. U. P. 2:193-201.

Cort, W. W. MacMullen, D. B and Brackett, S. 1937. Ecological studies on the cercariae in *Stagnicola emarginata angulata* (Sowerby) in the Douglas Lake Region, Michigan. Journ. Parasit. 23:504-532.

Dubois, G. 1929. Les cercaries de la région de Neuchâtel. Bull. d. Soc. Neuchatel des. Sci. nat. 53:6-123.

Johnston, J. G. 1920. The life cycle of *Echinostoma revolutum* (Froelich) Univ. Calif. Publ. Zool. 19:335-388, Pls. XIX XXV.

McCoy, C. R. 1928. Seasonal fluctuations in infections of *Planorbis trivolvis* in the larval trematodes. Jour. Parasit. 15:121-126.

Manson-Bahr, P. and Fairley, N. H. 1920. Observations on Bilharziasis amongst the Egyptian Expeditionary Force. Parasitol. 12:33-71, Pls. III-V.

Miller, H. M. Jr. 1926. Behaviour studies on Tortugas larval trematodes with notes on the morphology of two additional species. Carnegie Inst. Year Book No. 25, pp. 243-247

—————1928. Variety of Behaviour of Larval Trematodes Science 68:117.

—————1929. Behaviour and reactions of larval trematode specially to changes of light intensity. Anat. Records 41:36.

————— and Mahaffy, E. E. 1930. Reaction of *Cercaria hamata* to light and mechanical stimuli. Boil. Bull. 59:95-103.

————— and Northup, F. E. 1926. The seasonal infestation of *Nassa obsoleta* (Say) with larval trematodes. Biol. Bull. 50:490-508, 2 pls.

————— and McCoy, O. R. 1930. An experimental study of the behaviour of *Cercaria floridensis* in relation to its fish intermediate host. Jour. Parasitol. 16:185-197.

Miller, E. L. 1936. Studies on North American Cercariae. III. Biol. Monogr. 33:7-125, 8 pls.

Rankin, J. S. 1939. Ecological studies on larval trematodes from Western Massachusetts. Jour. Parasit 25:309-328.

Rothschild, M. 1936. Gigantism and variation in *Peringia ulvae* Pennant, 1777, caused by infection with larval trematodes. Jour. Marine Biol. Assoc. U. K., U. S. 20:537-546.

Sewell, R. B. S. 1922. Cercariae Indicae. Ind. Jour. Med. Res. 10:1-372, 32 pls.

Singh, R. N. 1952. Studies on Strigeid cercariae from Northern India Part I. A new species of strigeid cercaria from *Indoplanorbis exustus*. Allahabad University Studies, 1952 pp. 19-25, 3 figs.

—————1952*a*. Studies on Strigeid cercariae from Northern India Part II. A new species of strigeid cercaria. *Cercaria sphericauda* from *Indoplanorbis exustus*. Proc. Nation. Acad. Sci., India 22:12-19, 2 pls.

—————1952*b*. Studies on a new species of *Clinostome* cercaria. Proc. Nation. Acad. Sci India 22:1-11, 2 pls.

—————1952*c*. The cercaria of *Plasmiorchis orientalis* Mehra, 1934. Proc. Nation. Acad. Sci. India 22:61-69, 4 figs.

—————1953. Studies on strigeid cercariae from Northern India Part III. Five new species of strigeid cercariae from *Indoplanorbis exustus*. Allahabad University Studies 1953, pp. 47-72, 7 pls.

Soparkar, M. B. 1921. The cercaria of *Schistosoma spindalis* (Montgomery). Ind. Jour. Med. Res. 4:23-32, 4 pls.

Srivastava, H. D. and Dutt, S. C. 1951. Life-history of *Schistosoma indicum* Montgomery, 1906-A common Blood-Fluke of Indian Ungulates. Current Science 20:273-275, 3 figs.

Wesenberg-Lund, C. 1934. Contributions to the development of Trematoda Digenea, Part II. The biology of the fresh water cercariae in Danish fresh waters. Mem. de L'Aca Roy. des Sci. et des Lett de Danemark Sec. Sci. (9), 5:1-223, 1-39 pls.

THE MUSCULAR SYSTEM OF *POLISTES HEBRAEUS* (*Fabr.*)*

By

R. D. SAKSENA

B. R. College, Agra

[Received on 13th December 1958.]

INTRODUCTION

Although a good deal of morphological work is being done in foreign countries, there is a great need for comprehensive morphological work on Indian Insect types. The present work was undertaken to fill up this gap. *Polistes hebraeus* (Fabr.) the common yellow-wasp has been selected as a type because it is found throughout the greater part of the country almost all the year round, and above all, the type is suitable for such a study.

ACKNOWLEDGEMENTS

I take this opportunity to record my gratitude to Dr. L. P. Mathur, D.Sc., formerly Head of the Department of Biology, St. John's College, Agra for his constant help and guidance.

MATERIAL AND TECHNIQUE

For the purposes of dissections the adults on wings were caught in hand nets, while the larval and pupal stages were collected from the combs. Dissections were performed under varying powers of a binocular microscope in normal saline immediately after killing the insects in cyanide bottles. They were then firmly fixed in hard paraffin (blaskened with soot) in small dissecting dishes.

OBSERVATIONS

Muscles are responsible for the movements of the various parts of the body. Like higher animals, insect-muscles are composed of striped muscle fibres. An insect has ten times as many muscles as man. Each muscle originates from a large area of one or other sclerite and is inserted on some chitinous ridge of a different piece, which is intended to be moved.

The musculature in *Polistes* may be described under the following three heads :—1. Muscles of the head; 2. Muscles of the thorax; and 3. Muscles of the abdomen.

Muscles of the head—Muscles of the head fall into the following groups :— 1. Muscles of the Mouth Parts; 2. Pharyngeal muscles; 3. Antennal muscles; 4. Cervical muscles.

The Mouth parts of *Polistes hebraeus* (Fabr.) are complicated structures, functioning as an efficient chewing apparatus. The musculature is, therefore, correspondingly complicated and its high development is directly correlated with the peculiar nest-building habits of this wasp. There are altogether six pairs of muscles connected directly with the mouth parts. Most of these muscles take their origin directly from the exoskeleton of the head capsule, while some arise from the tentorium.

*Abridged from the thesis submitted for doctorate degree.

The following muscles are associated with the mouth parts :—1. One Abductor and one Adductor *mandibularis*, one set with each mandible; 2. Two main maxillary rotators and two maxillary levators, one set on each side ; 3. A pair of labial adductors and a pair of abductors. The labrum has no particular muscle but is operated by a number of muscle fibres arising from the clypeus and inserted on the chitinous arm of the pharyngeal plate.

The Mandibular muscles—Owing to the hypognathous condition of the head, mandibles are ventral and cover the mouth. The jaw is articulated to the pleurostomal margin of the cranium by the outer edge of its triangular base and is actuated by a powerful muscle - the Adductor or the Promotor (Pl. I, Fig. 3, MA) It is a very large fan-shaped complicated muscle bundle, arising partly from the ocular apodeme and to a greater extent from the lateral walls of the head capsule reaching up to the middle of the inter-ocellar space. It is inserted on a very prominent apodeme on the inner apex of the base of the mandible. It is composed of several bundles of muscle fibres running posterad from a long apophysis and is consequently a powerful muscle to close the mandibles and to help in carrying out the function of gnawing, tearing and chewing. The surface of insertion of the mandibular adductor is remarkable in that it is a very broad flat structure at the base and continued into a slender apophysis nearly to the roof of the head capsule with bundles of muscle-fibres arising from it on the posterior side. Laterally the mandibular adductor gives branches arising partly from the ocular apodeme and partly from the geno-occipitalis.

The remotor of the mandible (Ma) which is a small muscle, arises from the ventrolateral wall of the cranium and is inserted to a small apodeme on the outer side of the mandibular base close to the posterior mandibular condyle.

The Maxillary muscles—The maxillary muscles comprise those which move this appendage as a whole and also those which bring the terminal lobes, palps and their segments into play. The appendage is worked by a muscle (Pl. I, Figs. 1 and 2, Md) arising from the lateral region of the gular area or from the epistomal bridge and is inserted on a small transverse apodeme at the ends of the cardo. These muscles, one on each side, lower the appendage in a vertical plane. It is further operated by a huge muscle arising laterad along the genoclypeal apodeme and inserted on the whole of the cardo-stipeal apodeme. These muscles, (GM and LM) one on each side, act as levators of the maxilla (Ml) From each of the inner and outer margin of the stipe arises a muscle, which is inserted on the galea and lacinia respectively for bringing these structures into play. A muscle (Fig. 2, Sl) originating from the inner posterior margin of the tentorium *longitudinal antennalis* is inserted on the inner margin of the stipe in the middle of its length and acts as a levator of this portion. The maxillary palp is operated by a pair of small palpal muscles (Mm) originating from the outer distal margin of the stipe and inserted on the basal segment of the palp. The muscles of each of the six joints of the palp arise from the distal end of the preceding segment.

The labial muscles—The labial adductors (Pl. I, Fig. 6, R) arise on the apodeme of the frontoclypeal suture, close to the meeting of the clypeofrontal branch of the tentorium with the clypeus and are inserted to the inner lateral angle of the labium. The retractor (N) of the labium is a fairly large muscle, which arises on the facial wall of the head capsule and is inserted at the extreme dorsal tip of the submentum. The levators of the glossae (L) originate on the lateral walls of the mentum and submentum and are inserted at the base of the glossae. The depressor of the glossae is a single median muscle arising from the base of the mentum. After running through the deep cavity of the mentum and submentum in between the two depres-

sors of the glossae, it is inserted at the base of the appendage. The labial palps are also provided with levators and depressors, which originate laterally in the walls of the mentum.

The labrum has no muscle of its own but it is connected to the epipharynx by means of a membrane. The epipharynx is drawn in by means of a muscle arising from the anterior surface of the buccal chamber and inserted on it laterally. Drawing in or out of the epipharyngeal membane moves the labrum in an antero-posterior direction.

Pharyngeal muscles —The pharyngeal cavity is increased by the contraction of a pair of muscles (Text Fig. 2) the *Dilatores cibarii* (Text Fig. 2, c) which originate from the clypeus and are inserted on the epipharyngeal surface of the cibarium (F). Its cavity is decreased by another pair of large muscles the *Retractores angulorum oris* (o) originating on the frons and inserted on the oral branches of the pharyngeal plate. These muscles further help in passing the food into the pharyngeal opening. A large number of small muscle fibres *D latores buccalis* (b) arising from the clypeus latero-ventrally, run towards the anterior side for a short distance and are inserted to the arms of the pharyngeal plate. A few fibres also run mesially. All these muscles increase the buccal and cibarial cavities and also help in pushing the food into the oral chamber.

A small sclerite of the shape of a drawn-out "S" borders the preoral cavity laterally and lies in between the maxilla and the hypopharynx and may be called *Hypopharyngeal suspensorium* (k). A muscle (t) originating from the lateral surface of the membrane enclosing the preoral cavity is inserted on the dorsal end of the arms of the pharyngeal plate. Another small muscle the *tentorial retractor* (T) of the hypopharynx originates from the ventral apodemal process of the *tentorium transversal* and is inserted on the pharyngeal plate which is drawn posteriorly. A muscle the *Dilatores post pharyngeales* (a) originates from the vertex posterolaterally and is inserted on the narrow end of the pharynx just before its passing through the occipital foramen. Two small muscles (D) the *dilatores oesophageales* dorsalis and *ventralis* arise from the postero-dorsal and ventral margins of the occipital apodeme respectively and are inserted on the corresponding sides of the oesophagus.

The salivary chamber is also dilated by two pairs of labial muscles, one arising from the prementum and the other from the lateral walls of the hypopharyngeal plate. These are inserted on the dorsal surface of the salivary chamber.

Antennary muscles—There are four muscles of the antenna. Two pairs, one smaller and the other slightly larger arise from the *tentorium longitudinal antennalis* and are inserted on the proximal and the distal apodemes of the condylar process of the scape respectively. There is one big levator originating from the anterior portion of *tentorium longitudinal antennalis* and inserted on the dorsal side of antennal apodeme. Another big depressor muscle originates from the posterior portion of the same and is inserted on the ventral side of the antennal apodeme. The other two smaller muscles originate from the internal and the external side of the same arm of the tentorium and are inserted on the internal and external side of the antennal apodeme respectively. These impart the antenna a sideways movement. The muscles of the pedicel originate almost on the whole length of the dorsal and ventral sides of the scape and are inserted on apodeme of the pedicel dorsally and ventrally. The flagellum is devoid of any muscle and consequently its joints can not be individually moved, although the nature of its articulation gives it a good amount of flexibility.

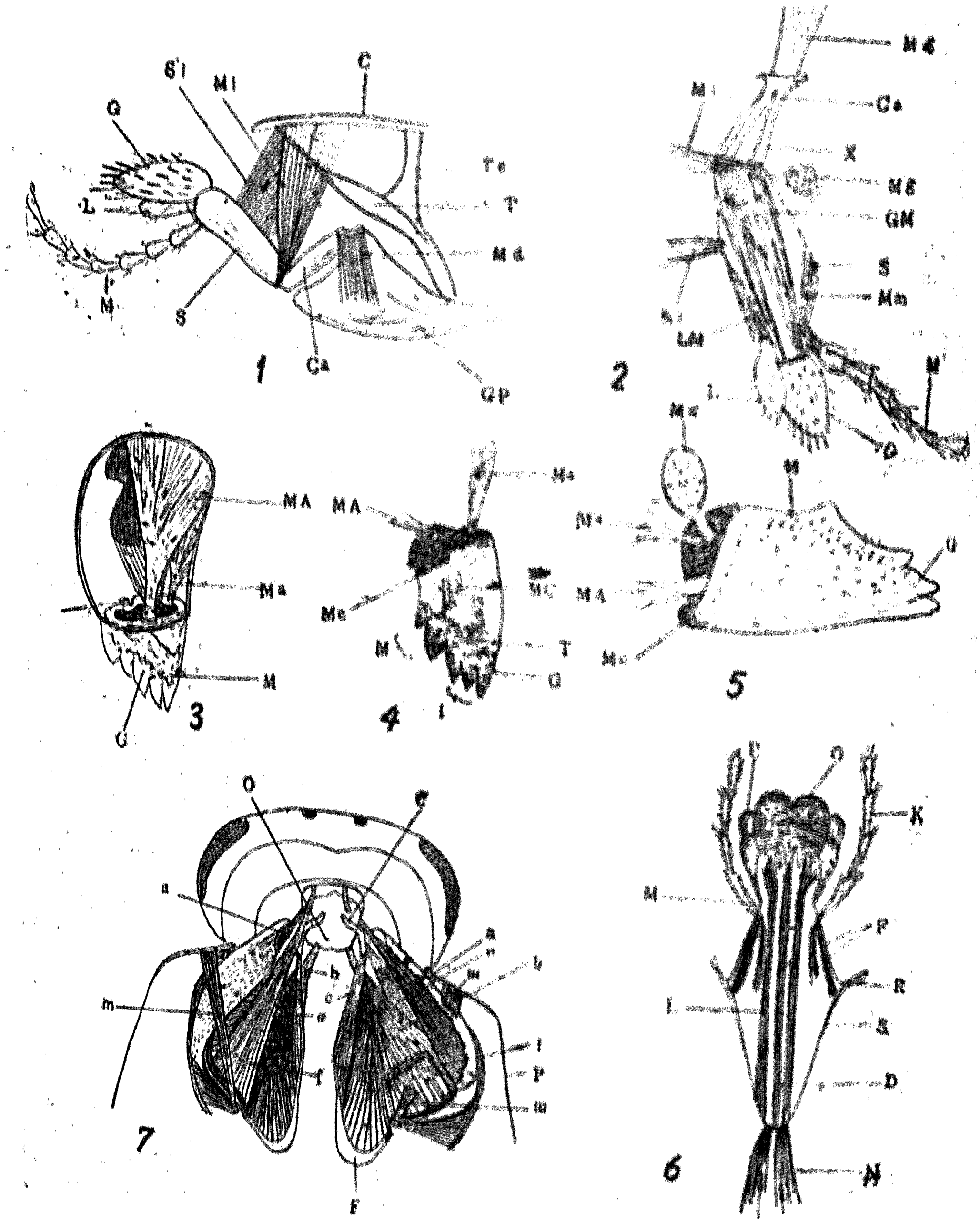


Plate I

Thoracic muscles of Polistes may be considered under the following heads :— 1. Muscles of prothorax, mesothorax and metathorax, 2. Muscles of the wings and 3. Muscles of the legs.

Muscles of the Prothorax—These include the muscles, which are attached to the various sclerites of this region and also those which connect it to the neck as well as the mesothorax.

Muscles of the neck—Only two movements of the head are possible, *viz.*, it can be moved up and down and to a very slight extent side-ways. The upward movement is effected by a pair of long muscles (Text Fig. 3, F), one on each side which originate from either lateral margins of the dorsal surface of the flat profurcal plate and after running in a forward direction, are inserted on the dorsolateral margin of the occipital apodeme close to the mesal line. Another pair (K), inserted laterally, originates from the sides of the propleuron. These muscles impart lateral movement to the head to a little extent. The head is depressed by a huge muscle which arises from the whole of the upper stout apophysis after receiving the muscle fibres from various directions and is finally inserted to the ventral side of the occipital apodeme.

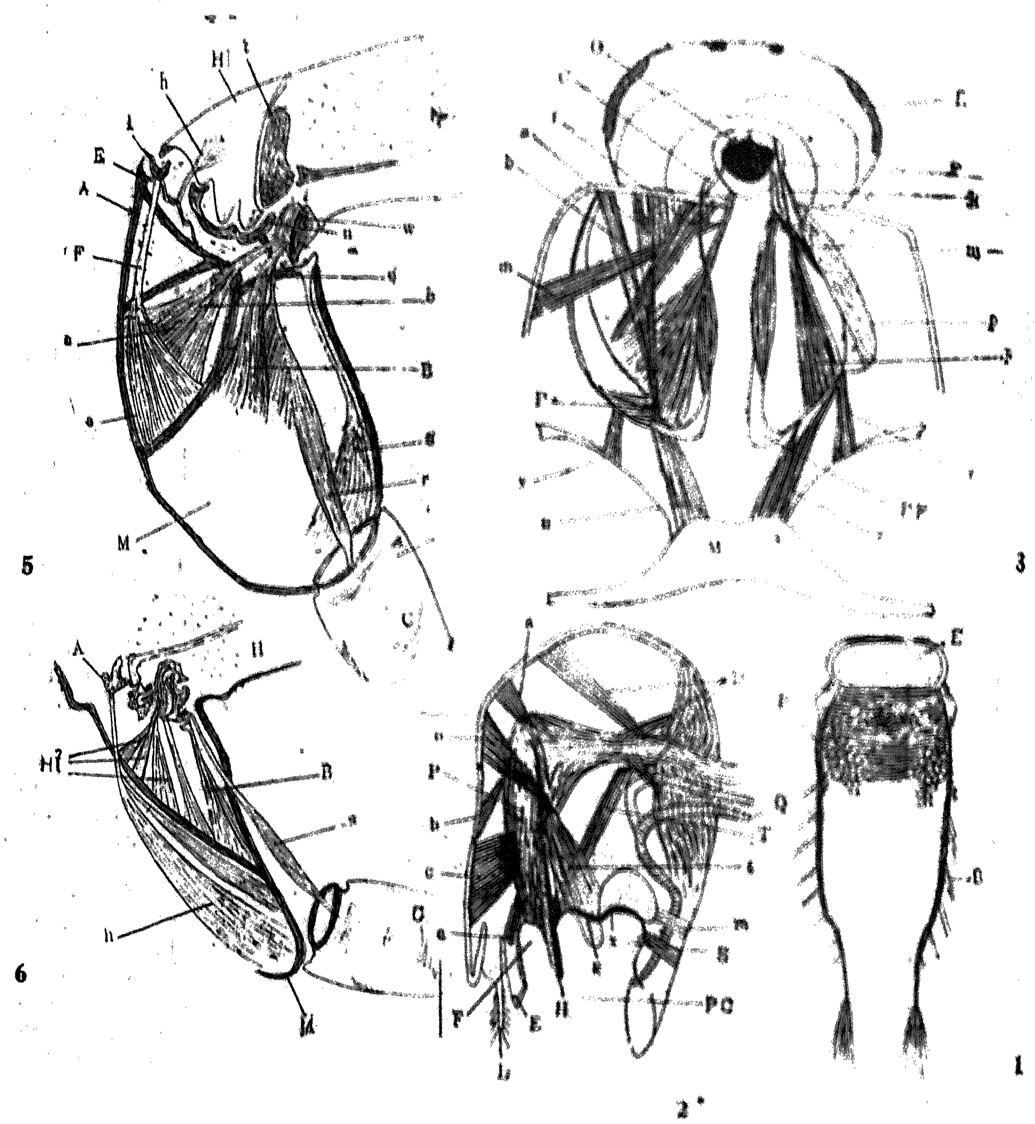
Other muscles —The head is further moved by two pairs of indirect muscles which are inserted on the small apodeme at the base of the cervical process of the propleura. One of them originates from the inner margin of the profurcal plate and another (m) from the anterior side of the propleura.

A small muscle (Pl. I, Fig. 7, m) binds the proscutellum to the propleuron. Other muscles, the tergopleurals connect the proscutum to the propleuron. They originate from the anterior margin of the proscutum close to each other and are inserted on the tip and the base of propleuron process. Another muscle originates from the anterior margin of the proscutum ventrally and is inserted to the tip of the propleuron process (e). The action of these muscles brings about an increase and decrease in the circumference of this region.

The proscutellum is connected to the mesoscutum by means of two pairs of muscles, one originates mesally and the other slightly laterally. They are inserted on the anterolateral margin of the mesoscutum (Text Fig. 3, P,F and r).

Muscles of Meso and Meta thorax—The entire meso and metathoracic space is occupied by a large number of muscles. These operate the wings directly or indirectly. The indirect wing muscles are very powerful and pominent and occupy nearly three-fourth of the space. They are not directly inserted to the wing base but stretch between the walls to the thorax. A contraction of these brings about a change in the shape of the thorax which ultimately results in imparting an upward or downward movement to the wings. There is another set of muscles, inserted to the wing base sclerites and they are responsible for directly moving the wings.

The horizontal indirect wing muscle is the largest muscle in the body and consists of a large number of bundles of longitudinal muscle fibres, running between the anterior phragma of the meso-scutum and the posterior phragma of the postscutellum. There are two masses of these bundles, one on each side of the middle line occupying nearly the whole of the median dorsal space of the thorax. This has been called the *Dorsal Muscle* (Text Fig. 4, Do) by Snodgrass. The *oblique dorsal* muscles, as found in other insects are absent in Polistes.



Text Figures

Lateral to these there is another huge muscle, which stretches dorso-ventrally between the mesothoracic tergite and the sternum and the ventral part of the pleuron. This muscle is called Tergo-sternal (K) by Snodgrass On contraction it reduces the curvature of the tergum which results in an upward movement of the wing. The relaxation brings about a downward motion. A similar change, although in a different plane, in the curvature of the mesothoracic tergite is brought about by the Dorsal muscle. The raising and depressing of the wings are the cumulative results of the action of both these muscles. The tergo-sternal muscles are functionally antagonists of the dorsals, because on contraction, they depress the tergum whereas the Dorsals elevate it. The contraction of the tergo-sternal results in raising the wings and that of the Dorsals in lowering them and vice versa. A small muscle arising from the propleura is inserted on the ventro-lateral aspect of the profurcal plates (Text Fig. 3, P.)

The Direct wing muscles are a set of small muscles which move the wing in a horizontal plane forwards and backwards; the movement being carried upon the pleural and notal wing processes. They lie against the inner surface of the pleuron (Text Fig. 5 and 6) and each wing is independently supplied with its own set.

The forewing is provided with an extensor (Text Fig. 5, F) which originates: from an apodeme on to the front part of the anepisternum of the mesothorax. It forms a long and thin apophysis, which after running along the anterior margin of the mesopleuron, is inserted on the parapteral plate, which coalesces with the anterior part of the wing base causing a forward movement of the wing on contraction. In wasps this muscle is very prominent and lies anteriorly.

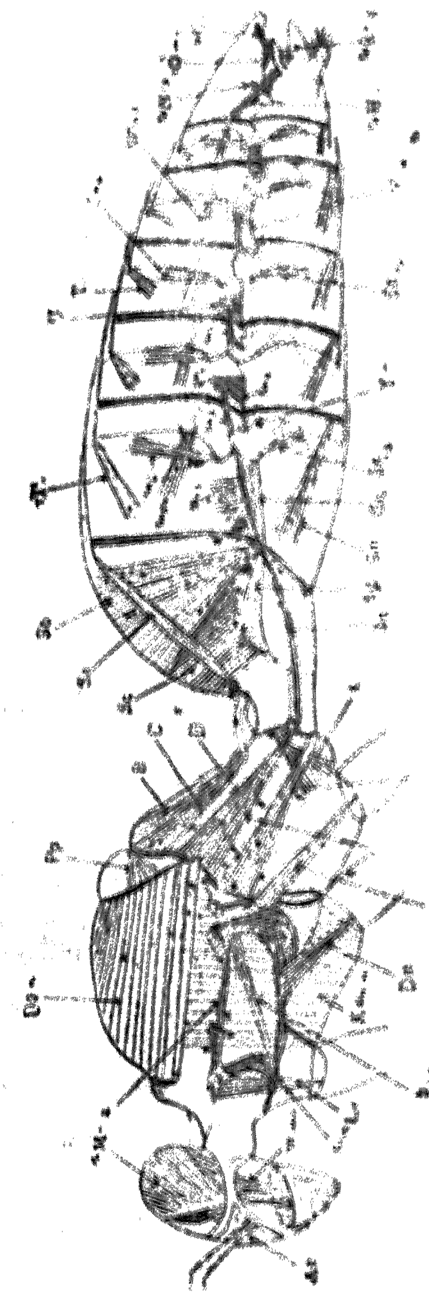
Its action is opposed by a set of two muscles the flexors,—jointly inserted on the 3rd. axillary of the wing base. In this wasp, they consist of two parts only, one originating from the anterior margin of the anepisternum (a, b) and the other from the middle of the episternum (c). They form long tendons before they are inserted to the 3rd axillary. Their contraction results in moving the wings backwards. According to Stellwaag the combined action of all these muscles gives the wings a semi-rotary movement. The extensor and the flexor muscles owing to their insertion on the axillaries, may be called the axillary wing muscles.

Besides the above there is a Basalar (Fig. 5, B) which in wasps has a coxo-axillary branch (Fig. 5, r) inserted to the Subalar plate. It mainly originates from the inner face of the episternum by a large number of muscle fibres, which form an apophysis, in the formation of which a large number of muscle fibres converging to a tendon-like structure attached to a coxa, also take part.

A Subalar muscle (Fig. 5 s) originates from the ventral portion of the episternum, runs along its posterior margin and is inserted by means of a tendon on the outer end of the scutellum. According to Stellwagg it depresses the wing process of the scutellum.

A small muscle inserted to the margin of the epimeron originates from the humeral plate (Fig. 5, h) This has not been recorded so far.

The hind wings also possess a similar set of direct muscles corresponding to those of the forewing but the indirect muscles are absent. The extensor of the hind wing is made up of two branches (Text Fig. 6, h) while the flexors have three (Hf)



The post scutellum is connected to the anterior face of the metathoracic furca by bundles of muscle fibres, which stretch in between them laterally (Text Figs. 3 & 4) A pair of muscles originating from the posterior tip of the profurca extends to the anterior tip of the dorsal plates of the meso furca on each side (Text Fig. 3, n and Text fig. 4, M) A second pair arising from the anterior arm of the mesofurca is inserted to the lateral arms of the profurca (Text fig. 3, r) A third pair (y) originating from the latero-ventral face of the dorsal plate of the mesofurca is inserted laterally close to the previous muscle.

Muscles of the leg—The muscles by which legs are attached, take their origin in their respective thoracic segments to which they belong and are inserted in the coxae at the proximal marginal apodemes. Muscles of the leg segments generally take their origin in the segment immediately proximal to the one on which they are inserted.

Muscles of coxa—In *Polistes hebraeus* the coxae are dorsally articulated to the pleura and ventrally to the sterna which limit their movements to a type of hinge with the axis in a transverse plane. They can consequently move in the anterior and posterior directions only. The musculature of the coxae is thus simple.

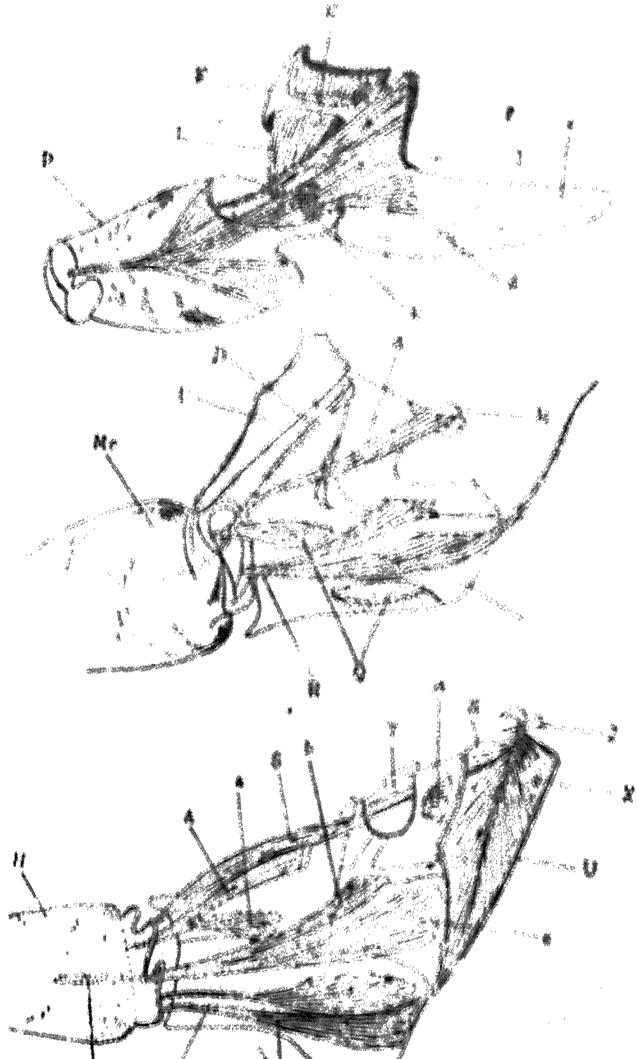
Coxal muscles of the foreleg—The coxa of the foreleg (Text fig. 7, P) is worked by a set of muscles which take their origin in the prothorax and are inserted on the proximal apodeme of the coxa. The muscle on the trochanter also assist it. The coxa is depressed by a muscle which arises on the propleuron (p) laterad and is inserted on the outer anterior margin of the coxal apodeme (Text Fig. 7, L) The other depressor originates from the lower side of the pro-sternal plate and is inserted to the inner anterior margin, pulling the leg forwards and inwards (Text fiig 7, d)

The levators are three in number. One of them originates from the tip of the postero-dorsal process of the lateral margin of the propleuron and is inserted to the posterior margin of the coxa. This muscle is extremely slender (Text fig. 7, f) The main levator, however, originates at the posterior margin of the above mentioned process of the propleuron, partly from its lateral surface and partly from the profurcal arm (Text fig. 7, l) It passes through the coxal cavity and receives a large number of muscle fibres from the inner and outer proximal surfaces of the coxa forming a long but broad apophysis, which is finally inserted on the dorsal apodeme of the trochanter. Another muscle, acting as a levator arises from the posterior lower side of the profurcal plate (F) and is inserted on the outer margin of the coxal apodeme (Text Fig. 7 K).

Coxal musculature of the middle leg—The levator (Text Fig. 8, Q) of the coxa is a big muscle which originates from the ventrally curved episternum at its outer margin and is inserted on the outer dorsal side of the coxal apodeme.

The depressor is a huge muscle composed of a smaller branch (Text Fig. 8, D), which arises from the ventral convex margin of the mesofurca and a bigger muscle trunk (d) from the mesal ridge of the mesosternum (M). It is inserted on the inner ventral side of the coxal apodeme.

A large muscle (R) which also acts as a depressor to the whole of the leg is composed of two branches, one smaller branch (1) originating from the arm of the mesofurcal apodeme which runs laterally along the metapleural suture and the other (2) bigger muscle bundle arising from the dorsal plate of the furca. Both of them form a long apophysis, which after passing through the coxa receives the fibres from the ventral area of the coxa. This apophysis is inserted on the trochanteral



7

8

9

Text Figures

apodeme ventrally. The bigger branch also receives a few fibres from out of the wing base sclerite and thus serves as subalar muscle as well.

The musculature of the hind coxa —The hind coxa is worked by the following muscles—two coxo-pleurals are inserted on the ventrolateral side of the coxal apodeme (Text Fig 9, B, C), one of these originates from the lateral side of the lower pleural plate and the ventral arm of the upper one, and the second from the ventral surface of the pleura and a few fibres from the metasterna (M). These muscles move the coxa anteriorly, the first a little outward and the second inward.

A delicate subalar muscles (Text Fig. 9 S) stretches across the dorsolateral coxal apodeme posteriorly and after passing through the foramen of the meta thoracic furca, joins the apophysis of the alary muscles lodged in the upper plate of the meta pleuron on its anterior side and is finally inserted on the second axillary (Z) of the hind wing. This muscle possesses apophyses at both ends with a few muscle fibres in between. During flight, the legs are kept freely hanging vertically, and the reason of it appears to be the action of the muscle.

Another big muscle consisting of a small branch (Text fig. 9, a) originating from the posterodorsal portion of the mesal ridge of the sternum and a big one (A) from the upper portion of the posterior face of the meta furca and lateral apodeme of the lower plate of the pleura, is inserted on the inner edges of the coxal apodemę on the dorsal side. This is the coxo-sternal muscle and draws the coxa upwards giving the leg a posterior movement.

Another very large muscle consisting of two branches originates from this region. The smaller branch (b) originates from the mesal side of the metafurca and the bigger one (c) from the lower portion of the meta furca. They form an elongated fairly broad apophysis (e). This enters the coxal cavity and during its course it receives muscle fibres from the ventral base of the coxa and is finally inserted on the ventral lip of the trochanter. This forms a very powerful muscle which depresses the leg and also stretches it.

Muscles of the trochanter—The trochanter forms a dicondylic hinge joint with the coxa by means of an anterior and a posterior articulation in a transverse plane resulting in the upward and downward movements of the distal portion of the leg. A huge muscle (Pl. III, Figs. 2 and 4, 0) originating in the metathorax has just been described. A few fibres (g) from the ventral area of the coxa join this long apophysis. It is further provided with a pair of levator muscles (Pl. III, fig. 2, i and fig. 4, N) which after originating from the dorsal wall of the coxa, are inserted on the antero-dorsal lip of the trochanter. They act as a depresser.

Muscles of the femur :—The movement between the trochter and the femur is very slight. The femur possesses a levator (Pl. III, Fig. 2. k) which originates from the dorsal margin of the femoral apodeme and a short depressor (f) which originates from the ventral surface of the trochanter and inserted on the femur ventrally. The femur, in fact, moves in a little forward direction under the influence of the coxo-trochanteral hinge.

Muscles of the tibia—A big levator (Pl. III, Fig. 2, x) originates from the lateral and to a certain extent from the dorsal walls of the femur. It forms a broad apophysis and is inserted on the dorsal margin of the tibial apodeme. Another big muscle (d) which occupies nearly half of the femoral cavity originating from the vental wall of the femur is inserted on the ventral margin of the tibial apodeme by means of a broad apophysis. This is the depressor. A number of fibres arising

from the dorso-proximal end of the femur and from the transverse apodemes at the proximal end of the femur join together to form a tendon-like apophysis (A) which runs through the femoral cavity and passes into the cavity of the tibia. This is the depressor of the tarsi, and after going through the cavities of the tarsi it is inserted on the unguitractor plate. Besides the above, a few fibres of the big depressor form another very slender apophysis (v) which is inserted on the dorsal lip of the tibia on the outer side, close to the insertion of the former muscle.

Muscles of the basi-tarsus—A big levator (Pl. III, Figs. 2n) originating from the inner dorsal margin of the distal third of the tibia, is inserted on the dorsal margin of the pretarsus apodeme.

The apophysis (A) which leads to the unguitractor plate receives a few fibres from the ventral margin at the proximal third of the tibia for about one third of its length in this region. It, later on, passes beyond into the pretarsal cavity and still further through other tarsi.

A few fibres arising from the proximal ventral side of the tibia join together to form a tender apodeme which is inserted at the inner marginal apodeme of the pretarsus and is a little mesad. This acts as another depressor muscle (b).

A big depressor muscle (a) originates from the distal third of the tibia mainly from its outer ventral sides, and is inserted on the outer margin of the pretarsus.

The Musculature of the Abdomen—The musculature of the abdomen is rather relatively simple, some of the muscles found in the abdomen of the honey bee are absent in the wasp. The musculature of the third to the last apparent segment is typical and alike, while variations exist in the first, second and the terminal segments. These will be considered separately. Muscles in general originate from the inner surface of the tergites or sternites and their places of origin are generally marked by dark red or brown spots externally and are inserted on the marginal antecostal apodemes. All the sclerites, dorsal as well as ventral, have a transverse apodemal line in the posterior third with posteriorly directed loop laterad. In an external view this appears to be a brownish black line with perforations. To this apodeme is attached the intersegmental membrane and the area of the sclerite lying on its posterior side overlaps the following segment and is free from any attachment of muscles. All muscles thus arise anterior to this inter-segmental apodemal line. Muscles are also inserted on the antero-lateral triangular processes of the antecostal apodeme of each sclerite.

THE MUSCULATURE OF A TYPICAL ABDOMINAL SEGMENT

The musculature of a typical abdominal segment may be considered under two main heads viz., those originating from the tergites and those from the sternites.

(*a*) *Tergal Muscles*—The following muscles have their origin on the terga :—

1. A pair of fairly large muscles, one on either side, originating antero-laterally just behind the broad ante-costal apodeme, runs mesially and is inserted to the narrow antecostal apodeme of the following tergum. This is homologous with the external dorsal muscle and its contraction brings about a drawing-in of the segments resulting in reducing the length of the abdomen but increasing its circumferenee (Text Fig. 4, T). The internal dorsal muscle is absent in wasps.

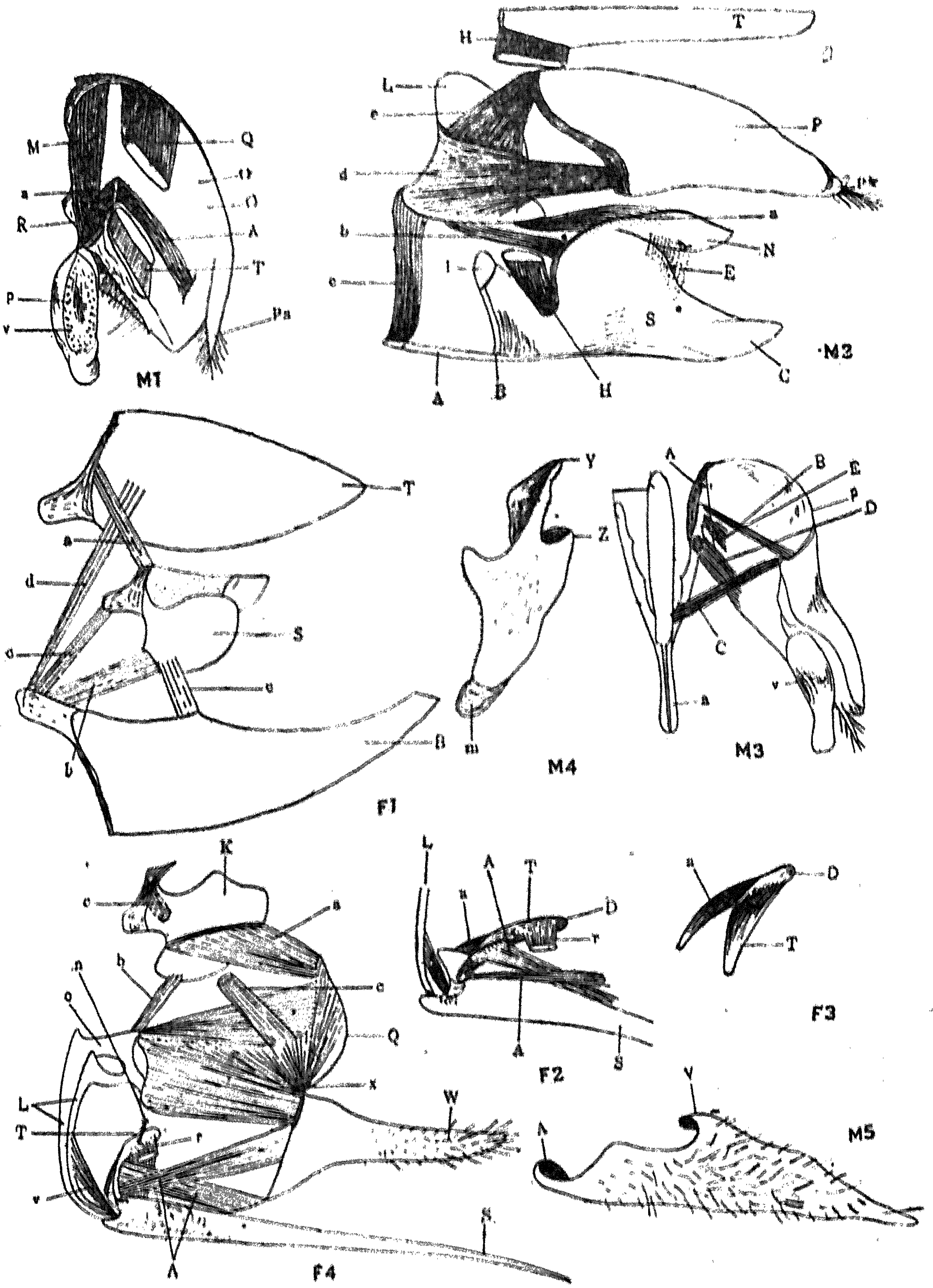


Plate II

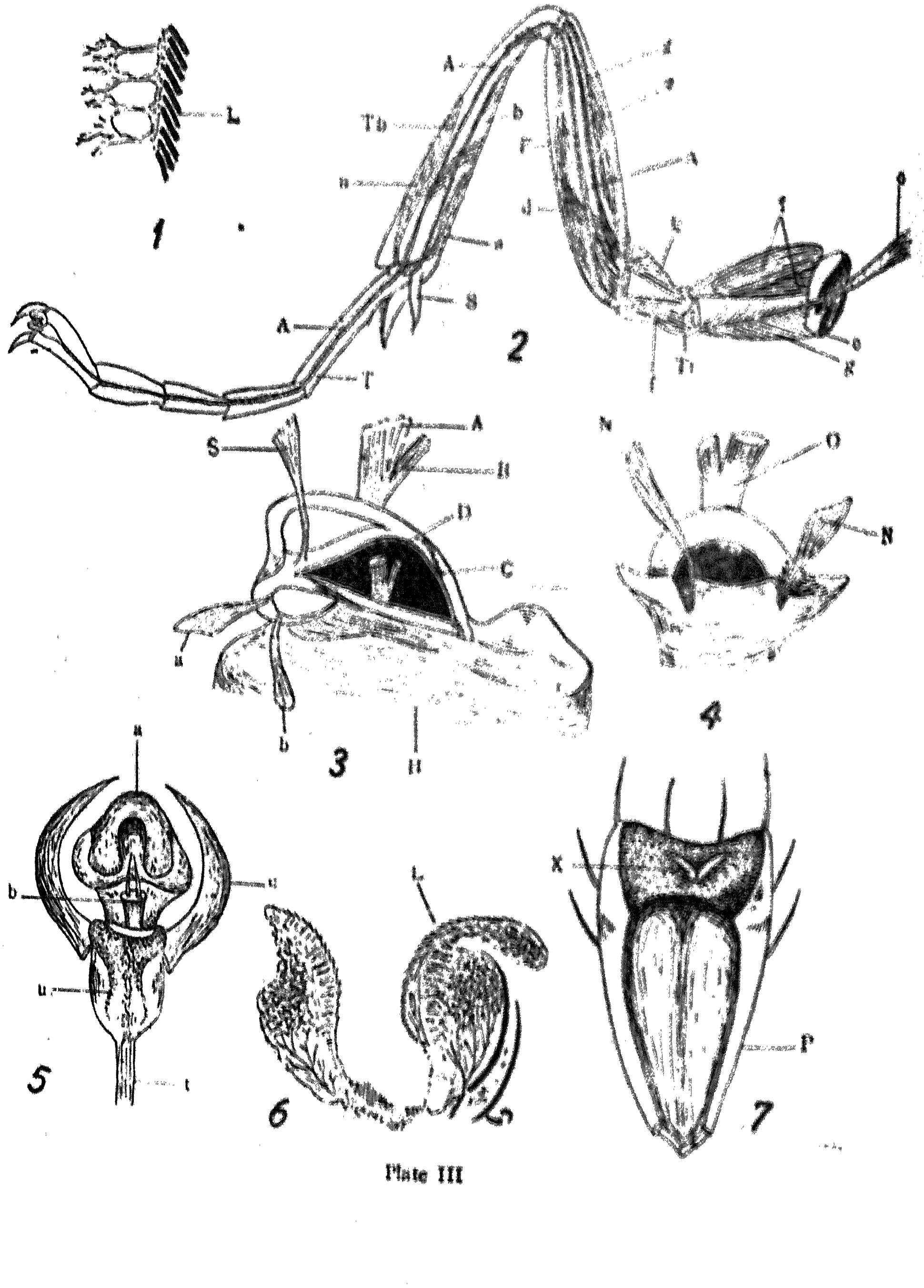


Plate III

2. A pair of thick but short muscles (Text Fig. 4, U) originates laterally behind the antecosta and is inserted along the outer lateral margin of the corresponding sterna. Its contraction brings the sternite closer to the tergite thus depressing the body and reducing its circumference. It is the main Tergo-sternal muscle.

3. A pair of small muscles (Tm 3) originates laterally from the tergite, somewhat dorsad of the tergo-sternal muscles close to the anterior margin and is inserted on the posterior margin of the lateral process of the corresponding sternite. On contraction it draws the anterior margin and helps in awarding curvature to the body provided the ventral muscle also simultaneously contracts.

4. Another small Pair (v) originating on the tergite a little posterior to the muscle described above, is inserted on the outside of the large antecostal apodeme of the corresponding sternite. These two muscles work in harmony and probably also draw out the sternite to elongate the body.

Besides the dorsal muscle, two other pairs of muscles further establish the intertergal relations. One of these two pairs (Text Fig. 4, w) originating from the large antecostal apodeme slightly dorsal to the tergo-sternal muscle, runs postero-ventrally and is inserted on the outer margin of the base of the antero-lateral tergal process of the following segment. This brings the proximity of the tergites closer. The second pair (x) originates from the intersegmental apodemal loop and is inserted on the anterior tip of the antero-lateral tergal process of the following segment. This imparts curvature to the tergites. The tergites and the sternites are further held together by means of a small muscle (y) which originates from the inner lateral margin of the tergite and is inserted on the outer posterior margin of the lateral triangular process of the corresponding sternite.

(*b*) ***Sternal muscles***—The following muscles have their origin on the sterna :—

1. One pair of elongated muscles, originating from the lateral antecostal processes running mesially, are inserted on the narrow anterior antecostal apodeme of the next-sclerite. This is the *External Ventral muscle* and it serves the same purpose as the *External Dorsal* (Text Fig. 4, Sm).

2. A large muscle (Sn) originates from the intersegmental apodemal loop and is inserted on the outer surface of the antecostal process of the following sternite This muscle counteracts the other Tergo-sternal muscles (U and V).

MUSCULATURE OF THE PROPODEUM

From the propodeum arise the muscles which are responsible for the movement of the abdomen as a whole. The abdomen is depressed by a pair of muscles (Text Fig. 4, A) one on each side, and these arise laterad on the metasternum and are inserted on the inner lateral margins of the first abdominal sternite bordering the petiole anteriorly. These are short stout muscles and lie mesially in the propodeum.

The levators of the abdomen are composed of two pairs of muscle bundles, one pair originates from the inner surface of each lateral half of the propodeum separately and forms a broad elongated apophysis (Text Fig. 4, B) the other pair of muscle bundles (C) arises from the postero-dorsal inwardly curved margin of the metathorax and forms a long stout apophysis, which meets that of the first pair. The two apophyses again meet to form a common median tendon which is inserted on the transverse apodeme at the base of the petiole.

Two bundles, one dorso-lateral and the other just ventral to it, arise from the inward projection of the two posterior margins of the dorsal plate of the metapleuron and are inserted more or less separately on the lateral petiolar notch. The dorsal muscle (D) draws the abdomen sideways and upwards and the ventral (E) a little downwards.

Another muscle (F) originates from the middle of the dorso-lateral arm of the metafurca and is inserted on the ventro-lateral side of the first abdominal sternite along the ventral petiolar margin. This muscle draws the abdomen inwards and downwards.

MUSCULATURE OF THE SECOND SEGMENT

The anterior end of this segment forms the petiole to which a number of muscles are inserted as discussed under the musculature of the propodeum.

The main tergal muscles of this segment are:—

(1) a pair of dorsal muscles (Text Fig. 4, Sa) which correspond to the *Internal dorsal muscle* of a typical segment (T). Both the muscles originate from the anterior portion of the tergal dome close to the transverse rod-like apodeme at the base of dorsal petiolar region and are inserted on the narrow antecosta of the third tergite. This results in drawing the third tergite closer and thus straightening the angle between the second and third sternite.

(2) A huge muscle (Sb) originates dorsolaterally from the dome and is inserted on the outer postero-lateral margin of the sternite where the antero-lateral margins of the third tergite and sternite are fused together. This muscle is formed by an aggregation of a large number of muscle fibres which are inserted on the lateral processes of the antecosta. It supplies firm attachment of the abdomen to the petiolar segment, and also keeps it straight, resisting against its hanging vertical to the body, due to the alimentary canal and genital apparatus being lodged in the posterior region making that portion comparatively very heavy.

(3) A very thick muscle (Sc) originates from the lateral and anterior side of the dome and is inserted on the outside of the vertically raised lateral portion of its own sternite. This is the promotor and is homologus to the *Terga sternal muscle* of the typical segment (Text Fig. 4, U).

(4) In the second sternite there is lodged only one pair of muscles (Sd) which takes its orig'n from the angle of the above mentioned vertically raised portion of the sternite and is inserted internally on the rim of its own lateral ends.

(5) A slender muscle (Se) also runs in between the petiolar notch and the lateral angle of the second segment. Its contraction brings about the bending of the abdomen.

MUSCULATURE OF THE THIRD SEGMENT

The musculature of this segment corresponds to a typical segment except that a muscle originates from the anterior margin of the lateral process of the sternite and is inserted on the postero-lateral angle of the second segment. (Text Fig. 4, So). This is homologous to the muscle (Tm 3) of a typical abdominal segment.

The usual set of muscles found between any two segments connect the telson to the preceding tergite. The telson is attached to the corresponding sternite by means of a long stout muscle (Text Fig. 4, G) originating from its posterior tip laterad and inserted on the margin of the lateral process of the sternite. Another muscle (H) originates from the lateral side of the anterior antecosta of the telson and is inserted on the sternite slightly anterior to the insertion point of the former muscle. A third muscle (N) takes its origin from the telson laterally and is inserted at the base of the triangular process of the corresponding sternite. A small muscle (O) also originating on the lateral side of the telson, is further inserted close to the posterior end of the big process of the sternite laterad. A short but thick muscle (R) originates from the mid-lateral side of the eighth sterna and is inserted to the inside of the apodeme bordering its own process. This muscle, gives an impression that the processes are vestiges of the following tergite. The author, however, attaches little importance to this because there is no other structure like the presence of a spiracle on this process to confirm the view. He, therefore, considers it to be a process of the sternite because the thick apodeme on the lateral side of the sternite continues without a break over this process.

A fairly large muscle (Plate II, Fig. M2 H) originates from the antero-lateral side of a small hexagonal plate, covered by the telson and is inserted on the lateral notch of the eighth sternite. The position of this plate suggests it to be the next tergum *i.e.*, the ninth, because it is covered over completely by the telson and lies next to it. The lateral margins of this plate are also overlapped by the sternite corresponding to the telson. The muscle mentioned above may be considered to be homologous with any tergosternal muscle as found in any other segment. A huge muscle (a) originating from the inner surface of the lateral process of the eighth sternite and after running anteriorly, is inserted on the *lamina annularis* which ventro-anteriorly fits over the parameres. Nearly parallel to this muscle, another (b) takes its origin and this is inserted at the base of the fan-like process of the eighth tergite. A very big muscle (c) originates from the convex surface of the anterior margin of the lamina annularis and is inserted to the anterior half of the anteriorly directed process of the eighth sternite. This muscle is a modified form of intersegmental muscle of other segments. A muscle (E) connects the lateral process of the eighth sternite to itself internally.

The *lamina annularis* is connected to the parameres internally by two pairs of muscles, one (d) originating from its anterior round margin, is inserted to the anterior marginal apodeme of the paramere ventrally and the other pair (e) originates from the transverse apodeme of the lamina annularis more or less in the same direction and is inserted dorsally on the anterior margin of the paramere.

A fairly thick muscle (Pl. II, Fig. M3, A) originates from the posterio-lateral process of the penis and is inserted on the side of the anterior apodeme of the paramere. From the ventral process of the paramere originate two muscles, one (B) which is inserted on the tip of the lateral process of the aedeagus and the other (C) on the anterior half of the penis laterad. On the dorsal marginal apodeme of the aedeagus there originates muscle (D) which is inserted on the outside of the lateral apodeme of the penal process. Another muscle (E) originating from dorsal surface of the paramere internally, is inserted on the tip of the lateral process of the aedeagus.

The volsellar musculature consists of four bundles of muscles. One of these four is the retractor of the volsella (Pl. II, Fig. 1, M) which originates from the

anterior surface of the paramere and is inserted on the dorsal apodeme of the volsellar plate; another (A) is the protractor which originates from the postero-dorsal surface of the paramere and is inserted on the anterior apodeme (a) of the volsella. A third muscle (Q) is also found in *Polistes hebraeus*. It originates from the dorso-lateral surface of the paramere and is inserted along the ventral margin of the volsellar plate; the fourth muscle (R) which is an intrinsic muscle runs between the anterior and the dorsal apodemes of the volsellar plate.

MUSCULATURE OF THE FEMALE TELSON

The musculature of the apparently last segments of the female abdomen corresponds to that of the male in all respects. The form of the telson in the two sexes differs. In the female it has an acute tip and in the male it ends in a round margin. The corresponding sternite is very different in the two. In female it is more or less similar to the telson and slightly longer posteriorly but in males it possesses a different form. The next segment is enclosed between the telson and the corresponding sternite. Its musculature consists of a long oblique muscle (Pl. II, Fig. F1 a) originating from dorso-lateral surface of the telson close to the antecostal apodeme and is inserted on the dorsal apodemal ring of the following tergite *i. e.*, the eighth, which is also called *spiracular plate*. Another muscle (h) originates from the antero-ventral lobe of the eighth tergite and is inserted on the dorsal margin of the triangular process of the seventh sternite. A third muscle (c) arises from the lateral triangular process of the spiracular plate and is inserted on the tip of the lateral process of the seventh sternite. Just underneath the antecostal ring of the eighth tergite passes the gut. A large muscle (d) originates from the lateral portion of the under surface of the telson and is inserted a little anterior to the lateral process of the seventh sternite. A small muscle (e) arises from the outer surface of the ventral lobe of Spiracular plate and is inserted on a process in the lateral margin of the seventh sternite.

MUSCULATURE OF THE FEMALE GENITALIA

The eighth tergite is connected to the quadrate plate by means of a number of muscles. A muscle (Pl. II, Fig. 4, a) originates from the inner oblique apodeme of the spiracular plate on either side and is inserted on the dorsal top of the quadrate plate or the eighth tergite. Another small muscle (b) originates from the antero-ventral margin of the spiracular plate and is inserted on the dorsal angular process of the triangular plate or the first valvifer. Another small muscle (c) originates from the outside of the quadrate plate in the middle margin and is inserted on the anterior apodeme of the Spiracular plate.

EXPLANATION OF PLATES

PLATE I

Fig. 1. A lateral view of the labium with its attachment to the tentorium. C=Clypeus; Ca=Cardo; G=Galea; G. P.=Gular plate; L=Lacinia; M=Maxillary palp; Ml=Maxillary levator; Md=Maxillary depressor; S=Stipes; Sl=Levator of Stipes; T=Tentorium longitudinal antennalis; Tc=Clypeo-frontal branch of the Tentorium longitudinalis.

Fig. 2. The maxilla with the component parts and musculature. Ca=Cardo; G=Galea; GM=Muscle of the Galea; L=Lacinia; LM=Muscles to operate lacinia; Mm=Muscles to operate maxillary palp; M=Maxillary palp; Md=Maxillary depressor; Ml=Maxillary levator; Mg=Maxillary gland; S=stipes; Sl=levator of the Stipe; X='y' shaped endoskeleton of cardo.

Fig. 3. Diagrammatic view of the laterally dissected head to show the musculature of the mandibles. G=Grinding surface of Mandible; M=Mandible; MA=Mandibular adductor; Ma=Mandibular abducter.

Fig. 4. Mandible of a worker. G =Grinding surface of Mandible ; I = Incisor lobe of the mandible, M =Molar lobe of the mandible ; MA = Mandibular adductor ; Ma =Mandibular abductor; MC=Mandibular carinae ; Mc=Mandibular condyle ; T= Tridentate ridge of the mandible.

Fig. 5. Mandible of a male. Mg =Mandibular gland. For rest See Figs. 3 and 4.

Fig. 6. The dosal view of the labium with its musculature. D=Depressor of glossa ; F=Muscles of the labial palp. (Levators and Depressors). G =Glossa ; K =Labial palp ; L =Levator of glossa; M =Mentum ; N =Labial retractor ; P =Paraglossa ; R =Labial adductor ; S =Submentum.

Fig. 7. Dorsal view of the musculature of neck after removing the pro-terga and partly the scutum of the mesothorax. a =Rotator of head ; b=depressor of head ; C e,=Indirect muscles of the head ; f= Levator of head ; F=Plate of the profurca ; G=cervix and cervical plates ; m =Muscles of the prothorax; O =Occipital foramen ; P, =propleuron.

PLATE II

Fig. M1, Ventral view of the musculature of the paramere. A=protractor of the volsella ; M=retractor of volsella ; O =paramere ; Q & R =muscles of the volsella ; a =apodemal process of volsella; p=sensorypapilla over the digitus ; ps=parameral spine ; v =volsella.

Fig. M2, Lateral view of the musculature of the male genitalia. A=anterior process of the eighth sternite of male ; B= anticostal ridge ; C =clasper ; a-e, H=muscles of the male genitalia ; N=lateral process of the eighth sternite ; P =paramere ; L =lamina annularis ; I=lateral triangular process of tergites and sternites ; S=VIII. sternum ; ps =parameral spine.

Fig. M3, Dorsal view of the musculature of aedeagus. A-E =muscles of the penis ; a=aedeagus p=paramere ; v=volsella.

Fig. M4, the digitus plate of the volsella. m =membranous lobe of digitus ; Y=mesial process of digitus; Z = lateral process of digitus.

Fig. M5, the cuspis plate of the volsella. A =apodeme ; V =dorsal process of the volsella.

Fig. F1, Lateral view of the musculature of the eighth tergite. a-e =muscles of the female telson; B=seventh sternum ; S =spiracular plate ; T =telson.

Fig. F2, Lateral view of the musculature of the triradiate plate. a =arms of the triradiate plate : D=dorsal ridge of the triradiate plate ; other lettering as in F4 below.

Fig. F3, Dorso-lateral view of the triradiate plate (lettering as in F2).

Fig. F4, Lateral view of the musculature of female genitalia, showing its muscular connection with the Spiracular plate. A =muscles which protrude out the sheath of the sting ; K=spiracular plate; L =lancets S, =sheath ; T, =triradiate sclerite ; Q, quadrate plate ; a-c =muscles of the female genitalia ; n, o =first valvifer ; r=muscles which draw in the sheath of the sting ; v, e= muscles, to operate the sheath of the lancets.

PLATE III

Fig. 1. A transverse section of the arolium lamillae (L) of the arolium (under high power).

Fig. 2. Musculature of the waspleg. A, a, b=depressors of the tarsi ; F=femur ; S=spur ; T=Tarsi ; Tr = Trochanter ; Tb =Tibia ; D =depressor of tibia, c, =Coxa, F =Depressor of Femur ; k =Levator of femur ; i =levators of trochanter ; n =Levator of basi-tarsus, o =Levator of hind coxa; x=Levator of tibia ; y =levators of slender apophysis.

Fig. 3. Dorsal view of the proximal end of the hind coxa. A, B, C, D=Levators of hind coxa ; H=Coxa of hind leg ; S =Subalar ; a, b =Coxopleurals of hind leg.

Fig. 4. Dorsal view of the proximal end of the trochanter. N =levators of trochanter ; O =Levator of the hind coxa.

Fig. 5. Dorsal view of the claws with arolium and unguitractor plate ; a =Arolium ; b=Chitinous bar ; c =claw ; t=First tarsus ; u =Unguitractor plate.

Fig. 6. Transverse section of the arolium. L =Lamellae of the arolium.

Fig. 7. Dorsal view of the pretarsus showing the knobs for articulating with the claws. P =Pretarsus X =Knoblike processes of the pretarsus to articulate with claws.

EXPLANATION OF TEXT FIGURES

Fig. 1. Ventral view of the pharyngeal plate. B=suspensorial rods; E=epipharynx; P=pharyngeal gland.

Fig. 2. Diagrammatic sketch of the lateral view of the head showing the buccal cavity, pharynx and oesophagus and their musculature. a=dilatores pharyngealis; b=dilatores buccalis muscle; c=dilatores cibarii muscle; e=dilator of the hypopharynx; D=dilatores oesophagealis dorsalis and ventralis; E=epipharynx; F=Cibarium; H=hypopharynx; k=hypopharyngeal suspensorium; L=labrum; m=labial muscle; o=retractores angulorum oris muscle; P=pharyngeal plate; PC=preoral cavity; Q=salivary duct; T=tentorial retractor of the hypopharynx; x=chitinous bar at the base of the preoral cavity to form the suspensorium; ta=small pharyngeal muscle; S=salivarium.

Fig. 3. Dorsal view of the musculature of the prothorax. C=cervical and [illegible] plates; E=eye; F=levator of the head; P=a muscle between the propleuron and prosternum; M=[illegible]; PF=plate of the profurca; a, b, f=tergopleuron muscles; k=rotator of head; m=[illegible] muscles of the head; O=occipital foramen; p=propleuron; x=subganglionic plate of the [illegible]; r, n, y=[illegible] muscles.

Fig. 4. Lateral view of the muscles of the body of the right side. A-P=muscles of the propodeum; Ae=antennary muscles; Do=dorsal muscle; Dm=depressor of middle coxa; K=tergo-sternal muscle; L=levator of the procoxa; M=mandibular adductor; Pp=muscle on the posterior side of the propodeum; Q=levator of the hind coxa; H, G, N, O, R=muscles of the eighth segment of male; Sa, Sb, Sc, Sd, Se=muscles of the second segment; a, b, c=pleural muscles; m=[illegible] abductor; T-Y=tergal muscles of the abdomen; Sm, Sn, So=sternal muscles of abdomen.

Fig. 5. Lateral view of the musculature of forewing. A=An episternum; B=basalar muscle of forewing; C=coxa; E=epimeron; F=forewing; F=extensor of the forewing; H=humeral plate; M=mesopleuron; a-c=flexors of forewing; e=episternum; h=small muscle originating from the humeral plate and inserted on epimeron; I=first axillary sclerite; s=subalar muscle.

Fig. 6. Lateral view of the musculature of the hind wing. A=first axillary sclerite; B=[illegible]-axillary branch of basalar muscle; C=coxa; Hf=flexor of the hind wing; H=hind wing; M=[illegible]; h=extensor of the hind wing; s=subalar muscle;

Fig. 7. Lateral view of the musculature of coxa of the fore leg. F=Profurca; K, h, f, l=elevators of procoxa; P=coxa of the front leg; d=depressor of the procoxa; p=propleuron.

Fig. 8. Lateral view of the musculature of coxa of the middle leg. R, D, d=depressor of the middle coxa; M=Mesofurca; Mc=middle coxa; Q=levator of middle coxa; U=upper plate of metapleuron

Fig. 9. Lateral view of the musculature of the coxa of the hind leg. A=[illegible] muscle; a-c=levators of hind coxa; B, C=coxopleurals of hind leg; M=metasternum; H=coxa of the hind leg; T=metafurca; S=subalar; U=upper plate of metapleuron; X=muscle of the axillary sclerite; Z=second axillary sclerite.

BIBLIOGRAPHY

1. Berlandt, L. J., 1922 Notes Sur un nid de *Polistes gallicus*, *Ann. de la Science nat.* Paris, (10), Vol. 5, 435-404.

2. Berlese, A., 1909 Gli Insetti, *Societa Editrice Libraria*, 243 and 305, figs. 279 and 332.

3. Crampton, G. C., 1914 The ground plan of the typical Thoracic Segment in winged Insects. *Zool. Anz.*, 44:56-67.

4. ———— 1919 A phylogenetic study of the mesothoracic terga and wing bases in Hymenoptera, Neuroptera, Mecoptera, Diptera, Trichoptera and Lepidoptera. *Psyche*, 26 (9):53-64, Pl. 1 and 2.

5. Crampton, G. C., 1920 Remark on the basic plan of the terminal abdominal structures of the males of winged insects. *Can. Entomol.*, 52:178-183.

6. Macgillivray, A. D., 1923 External Insect Anatomy, Illinois.

7. Maki, Takadi, 1938 Studies on the thoracic musculature of Insects. *Mem. Fac. Sci. Agric.*, Taihoku Imperial Univ., 24 (1).

8. Morison, G. D., 1927 The Muscles of the Adult Honey Bee (*Apis mellifica*). *Quart. Sci.*, 71.

9. Newell, A. G., 1918 The comparative morphology of the genitalia of Insect. *Ann. Ent.*

10. Packard, A. S., 1868 On the structure of the ovipositor and homologous parts in the male insect. *Proc. Boston Soc. Nat. Hist.*, 11:393.

11. Peck, Oswald., 1937 Male Genitalia in the Hymenoptera (Insects). *Canad. J. Reseach*, 15 (11-12):221-274.

12. Pruthi, H. S., 1925 The morphology of the male genitalia in Rhynchota. *Trans. Ent. Soc.* London, 127-267.

13. ———— 1929 Homologies of the genitalia of Insects. *Entomol. Mon. Mag.*, 65:198-201.

14. Snodgrass, R. E., 1909 The thorax of Insects and Articulations of wings. *Proc. U. S. Nat. Mus.*, 36:511 595, pls. 40-69.

15. ———— 1910 The Anatomy of the Honey Bee, *U. S. Dept. Agr. Bur. Ent.*, Tech. Ser. Bull., 18:166.

16. ———— 1927 Morphology and Mechanism of the Insect Thorax. *Smith. Misc. Coll.*, 80 (1)—180.

17. ———— 1928 Morphology and evolution of the insect head and its appendages. *Smith. Misc. Coll.*, 81 (3) : 158.

18. ———— 1931 Morphology of Insect Abdomen. Part I, General structure of the abdomen and its appendages. *Smith. Misc. Coll.*, 85 (6) : 1-128.

19. ———— 1935 Principles of Insect Morphology. McGraw Hill Book Co. Ltd.

20. ———— 1941 The male genitalia of Hymenoptera. *Smith. Misc. Coll.*, 99 (4) : Pl. 33.

21. Stellwaag, F., 1910 Bau und Mechanik des Flugapparates der Biene. *Zeit. wiss. Zool.*, 95:512-550.

STUDIES IN THE MUCORALES

I. SYNCEPHALIS NODOSA VAN TIEGHEM

By

B. S. MEHROTRA

Botany Department, University of Allahabad

[Received on May 19, 1959]

Syncephalis is one of the few genera which constitute the family Piptocephalidaceae of the order Mucorales, the chief characteristic of the family being the production of few spored sporangia with the sporangiospores arranged in a linear manner. This genus has been described by Fischer (1892) as consisting of facultative parasites which take pleasure in settling on other Mucorales. However they can be cultivated saprophytically on dung. In nature they occur mostly in the form of parasites of other Mucorales. Even the various species have been found to parasitise each other—*Syncephalis cordata* van Tieghem u. Le Monnier has been observed on *Syncephalis cornu* van Tieghem u. Le Monnier.

Twenty five to 30 species of *Syncephalis* are said to be known (Hesseltine, 1955). In India, Ramakrishnan (1955) in his studies on 'Some Aspects of Soil Fungal Ecology' has listed two species of *Syncephalis viz.*, *S. cornu* van Tiegh. and Le Monnier and *S. reflexa* van Tiegh. which appeared on root bits buried in soil at Vandalur (near Madras). Ginai (1936) reported two isolates of *Syncephalis*—one from the dung of a donkey, though differing greatly in measurements from *S. sphaerica* van Tieghem was identified as such, and another isolate from the dung of a Zebra the specific identificati n of which was not made. Recently the author came across a *Syncephalis* parasitizing a species of *Mucor* growing on dung, most probably, of a 'wild rat' in the cold month of January, 1959 during the days having considerable drizzling rain and sunshine. It showed the characteristic features typical of the speci s, *Syncephalis nodosa* van Tieghem.

Description of the Isolate :

Vegetative mycelium inconspicuous in the substrate. Sporophores separate, erect, unbranched and stout, with rhizoids at the base which very often fuse with each other forming knotty extensions (Pl. 1, Fig. A, B, C; Pl. 2, Fig. 1 & 2B). Sporophore walls smooth (Pl. 1, Fig. D), hyaline but on aging wrinkled and slightly yellowish or reddish-yellow. Sporophores on maturity developing 2-4 knot like swellings at almost equal intervals with no transverse walls (Pl. 1, Fig. F.), 100-160μ in height, 5μ in width except at swollen areas where width is 8μ. At tip the sporophore enlarges into a vesicle, about 20 μ wide (Pl. 2, Fig. 2A). Basal cells deltoid to some what rectangular, 3-5 with as many spore chains, generally with two spores in each chain (Pl. 1, Fig. E). Spores barrel-shaped, blunt-rectangular, proportionately very large, 8-10μ by 6μ slightly verrucose to warty (Pl. 1, Fig. G, H), when single slightly coloured, in aggregate rust coloured.

No zygospores seen.

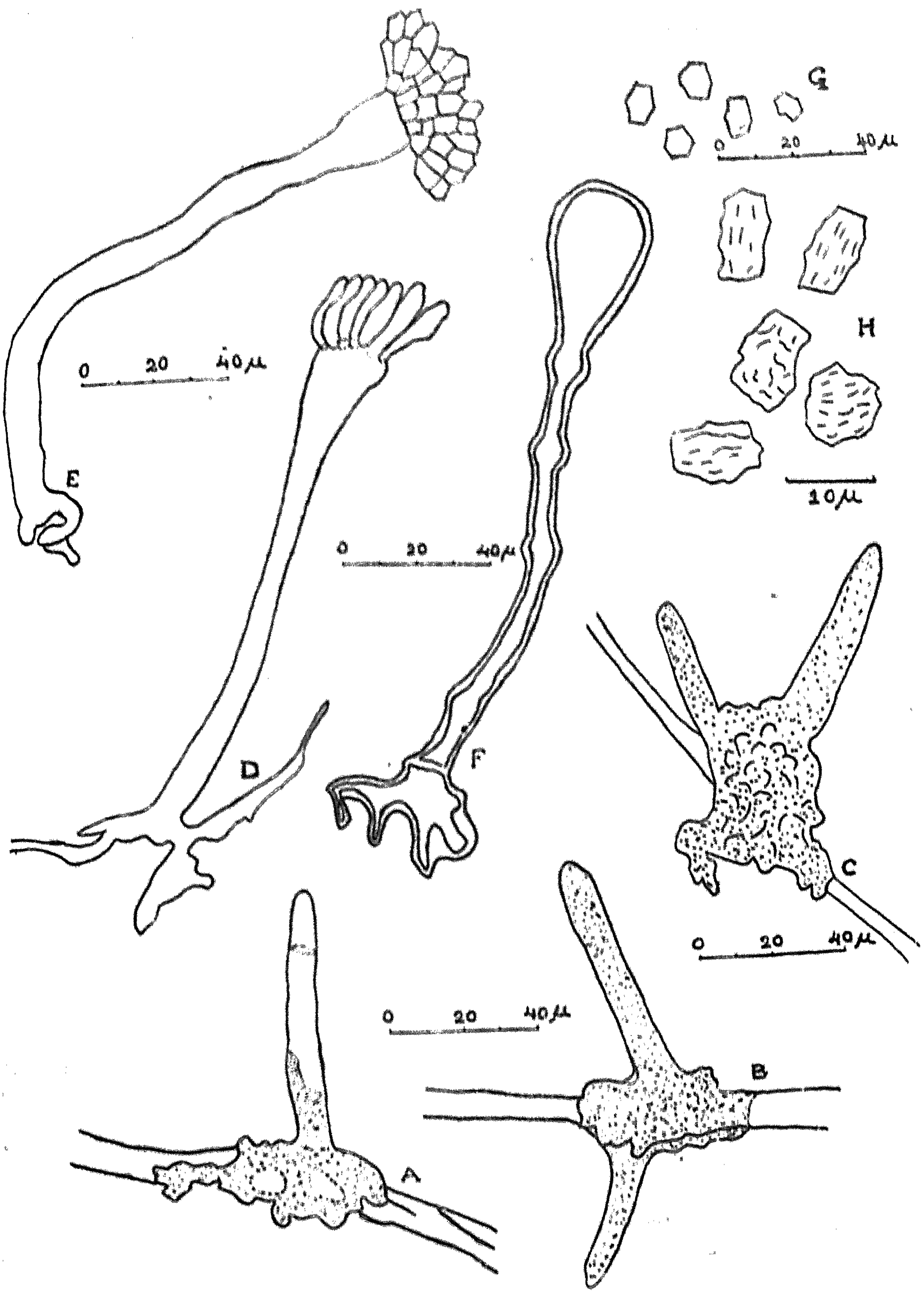
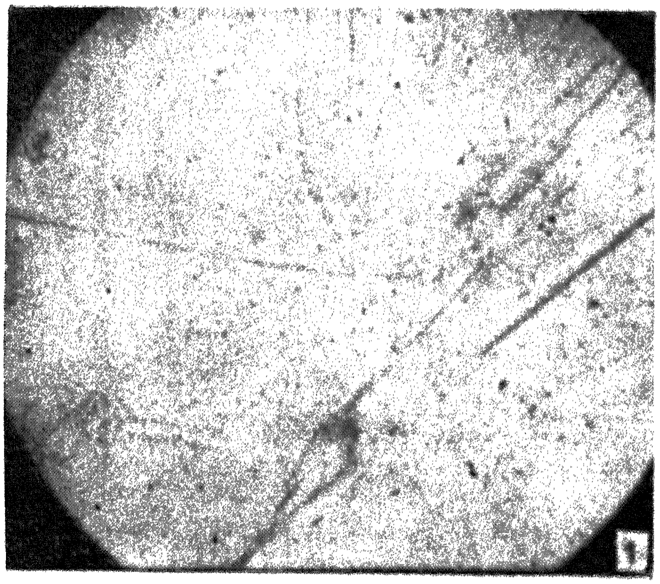


Plate I.—*Syncephalis nodosa*. Figs. A, B, C, developing sporophores on a hypha of *Mucor* : D, young sporophore with no differentiation of spores ; E, a fully developed sporophore ; F, a sporophore on maturity ;G, spores (x600) ; H, spores (x1600).



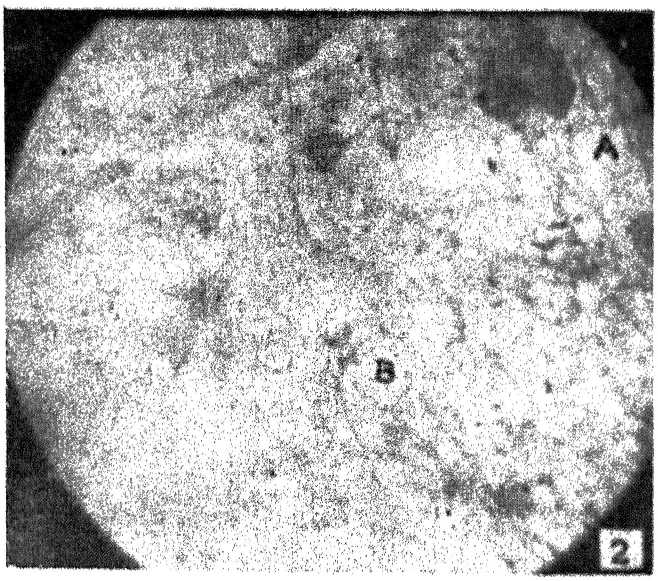


Plate 2.—*Syncephalis nodosa*. Fig. 1. Photomicrograph of developing sporophores (x150). Fig. 2 A, top part of a sporophore; 2 B young rhizoids (x300).

ACKNOWLEDGEMENTS

The author expresses his thanks to Dr. C. W. Hesseltine and Prof. R. K. Saksena for the encouragement.

LITERATURE CITED

Fischer, A. (1892). Phycomycetes: Mucorinae. In Rabenhorst's Kryptog. *Flora v. Deut. Oest. u. d. Schweiz*, 1 (4) : 294—308.

Ginai, M. A. (1936). Further contributions to our knowledge of Indian coprophilous fungi. *Jour. Indian Bot. Soc.*, 25 (5) : 269—284.

Hesseltine, C. W. (1955). Genera of Mucorales with notes on their synonymy. *Mycologia*, 47 (3) : 344—363.

Ramakrishnan, K. (1955). Some aspects of soil fungal ecology. *Proc. Indian Acad. Sci.*, 41(B) : 110—116.

CONTENTS

The Mission Press, Allahabad

PROCEEDINGS

OF THE

NATIONAL ACADEMY OF SCIENCES

INDIA

1959

VOL. XXIX SECTION - B PART II

UTILIZATION OF A MIXTURE OF AMINO ACIDS BY SOME SAPROLEGNIALES

By

RAM DAYAL

Department of Botany, University of Allahabad

Read at the 28th Annual Session of the Academy held at the University of Agra on 8th February, 1959.

All amino acids are not of equal value in fungus nutrition. Steinberg (1942) has made an extensive study on the utilization of 22 amino acids by *Aspergillus niger* and he found that seven out of them were excellent nitrogen sources. He held that these seven amino acids were primary and from them the secondary aminoacids were derived. Lilly and Leonian (1942) have reported that different amino acids vary in effectiveness. They also found that different strains of the same organism responded differently to the same source of nitrogen.

Lilly and Barnett (1951) have observed that a mixture of amino acids may or may not be better utilized than a single amino acid. The effect of a single amino acid on the utilization of another varies with the amino acids involved and the fungus concerned. Leonian and Lilly (1940) studied growth of *Phycomyces blakesleeanus* on five single amino acids and on their mixture. The growth on the mixture was much better than on the individual amino acids. More complex relations were found (Lilly and Leonian, 1942) by growing 10 strains of yeast upon sixaminoacids and on their mixture. Bilgrami (1956) carried on similar investigations by growing *Pestalotia mangiferae* and *Phyllosticta cycadina* on single amino acid as well as on their mixture. He reported that both good and poor amino acids were assimilated simultaneously from the mixture. Tandon and Bilgrami